ISSN 1800 – 4989 (Print)
ISSN 2719 – 2598 (Online) SLJM Vol 9 No 1: January - April 2023

Sri Lanka Journal of Marketing
University of Kelaniya - Sri Lanka

Influence of Codesign as a Cocreation Strategy on Constructability (Among Sri Lankan Architectural and Engineering Design Start-Up Practices)

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DOI: https://doi.org/10.4038/sljmuok.v9i1.120

ABSTRACT

This research looks at the influence that codesign has on the constructability of a project and how the client's knowledge impacts this relationship. Client knowledge is explored as a mediator. Further The factor that gave the largest contribution to codesign was the form of facilitation with a mean of 1.59, which was closest to the strongly agree point on the scale (number 1 was assigned to Strongly agree). The overall mean value of codesign was 1.82. Knowledge management gave the largest contribution towards constructability with a mean of 1.61. The overall mean of constructability was 1.70. The mediator, client knowledge had an overall mean of 2.10 with experience having the largest contribution with a mean of 2.08. Four hypotheses were tested. Hypothesis 1 was accepted since the correlation was 0.633, and its significance was 0.000, with the regression model fitting by 40.1%, showing that there was an impact on constructability from codesign. Hypothesis 2 was to test whether codesign and client knowledge were related, and it was proven, since correlation is reported to be 0.432 and its significance is 0.000, with the regression model fitting by 18.6%. Hypothesis 3 tested the relationship between client knowledge and constructability. It was also accepted in the correlation is reported to be 0.453 and its significance is 0.000 with the regression model fitting by 20.6%. Further, all factors in the three variables were validated through cross validation via thematic analysis, except for access to information. This could be because the client may not be able to interpret the information on their own. Hypothesis 4 investigated the mediator and an z value of 2.26 with significance of 0.000 indicates that client knowledge significantly mediates the relationship between codesign and constructability.

Keywords: *Codesign, Constructability, Project Feasibility, Client Knowledge, Cocreation*

1. INTRODUCTION

Lean has been described in many ways by different authors. Schonberger (1986) and Dahlgaard and Dahlgaard-Park (2006) describe lean and lean thinking as avoiding waste and thus designing low-cost developments. Burgess and Radnor (2013) focuses on the elimination of practices that do not add value. Gupta, Sharma and Sunder (2016) gives a more sophisticated definition as a combined multi-dimensional tactic involving a range of management procedures built on the idea of removing waste via constant development and describe lean as a way of thinking and not simply another management tool.

Coming into services, Grönroos (1990) defines a service as an/set of activity that are intangible, usually occurring in exchanges between customers and members/systems of the organisation delivering the service, providing value to the customer. . (Bocken and Snihur, 2020b; Gruber and Tal, 2017; Lenarduzzi and Taibi, 2016; Shepherd and Gruber, 2021)

The concept of lean thinking involves identifying value, removing non-value adding activities, strive for value production, allow the customer to pull value and integrate continuous improvement. (Womack and Jones, 1996, 2015) Codesign or cocreation is identified as a dimension of lean. It involves the customer in the design process, to help identify and deliver value. (Combrinck and Porter, 2021; Ingelsson, Bäckström and Snyder, 2020; Trischler *et al.*, 2018; Dietrich *et al.*, 2017) In the AE (Architectural and Engineering) industry, projects are the focus. Meaning that each individual client requirement has a defined goal, is unique, temporary, uses a variety of resources, and is new. It is also defined as a system – a collection of elements required to achieve a goal. Thus, managing all the components of a project becomes a huge task, which goes in as project management (PM). This research focuses on

how codesign impacts project management (PM), which is defined as a systems approach to management. A project life cycle consists of four stages namely, conception, definition, execution, and operation. Feasibility is a subcomponent of conception and is defines whether a particular design is practical for a project. Hence, this paper focuses on how codesign with the client impacts the technical feasibility or constructability of the design project. Constructability has also been known as buildability in the past. (John M. Nicholas and Herman Steyn, 2021; Helkkula, Kowalkowski and Tronvoll, 2018; Trischler *et al.*, 2018; Bondare *et al.*, 2017; Kifokeris and Xenidis, 2017; Richardson, 1997; Womack and Jones, 1996)

1.1. Context

This study is focused on the architecture and engineering design industries, which are a component of the construction industry. The global construction industry comprises of a market price of over USD 11 trillion. The Sri Lankan construction industry contributes to 7.4% of the GDP as of 2021. Hence, this industry is a massive contributor to both the global and Sri Lankan economies. Major challenges faced in the industry include how an individual practitioner or start-up should manage their practice as a business. The design components of the construction industry are highly interconnected with the customer (client), since the rest of the construction would depend on the design and the ability of the designer to adapt to changes required during the project. Viewing architectural and engineering practices as businesses is not common unless the firm reaches a high level of growth. While among architects and engineers, the prospect of marketing comes in a lot later, ensuring that value that is required by the client is delivered to them is of utmost importance to new and experienced practitioners. With new practitioners, specifically those involved in individual or freelance start-up practices, delivering the best value to the client could be a method of attaining competitive advantage, specifically through cocreation with the customer. However, practical implications of whether such cocreated projects are feasible exist. (Economic and Financial Reports | Central Bank of Sri Lanka., n.d.; Trischler et al., 2018; Bondare et al., 2017; Széchenyi István University, Kautz Gyula

Economics Faculty and Ercsey, 2017; Andrés-López, González-Requena and Sanz-Lobera, 2015; Jayasena and Weddikkara, 2012; Karpen, Bove and Lukas, 2012; Sacks et al., 2010; Magnusson, Matthing and Kristensson, 2003)

1.2. Research Gap

Lean service is a concept developed from lean manufacturing. It includes the application of lean principles to service industries. Since lean concepts advise the involvement of the customer in the product improvement process, lean services follow the idea of letting the "customer service themselves". (Sarkar, 2017) Hence, service industries such as the AEC (Architecture, Engineering and Construction) industry benefits from lean services. The biggest challenge for service organisations is providing an experience to the customer which is non-parallel. Unlike a product which can be improved, the service sector has only one chance to please the customer. If businesses were to spend more effort on creating a better service, they face the risk that the customers may be looking for service that is quite different from your hypotheses. Thus, letting the customer service themselves seems to be an appropriate approach. However, where to start this is questionable in literature. (Bocken and Snihur, 2020b; Sarkar, 2017; LaGanga, 2011; Ries, 2011).

Combrinck and Porter (2021) suggest codesign as an approach to allow the customer service themselves, in the architectural process, and the findings show that initial stages of the process could benefit from the constructive criticism of the client. Thus, the value required by the customer could be identified. However, whether codesign promotes feasible projects becomes an issue. Hence factors such as customer knowledge and engagement would affect the impact of codesign on the feasibility of projects. Further research is suggested in other service industries and on such factors. (Yen, Teng and Tzeng, 2020; Trischler *et al.*, 2018)

According to Priyadharsan and Lakshika, (2019), two major factor for the failure of new small businesses is lack of access to sufficient capital and low entrepreneur

competency. While this is common even to non-service businesses, product-based businesses do have the theoretical frameworks available which could be tested out in the corporate world. However, service industries face the same problem of investment and entrepreneur competency because they are unaware of how to eliminate choose the right minimal service to begin with and define the direction of improvement to their services. (Silva *et al.*, 2021; Priyadharsan and Lakshika, 2019; Gupta, Sharma and Sunder, (2016).

Moreover, since many start-ups are known to be based on the innovation of a product or technology, service domain businesses end up trying to include a product which they can develop to the maximum potential, as the product development gives them more clarity amidst the high stress environment of a start-up. However, it is shown that this is one of the main reasons for start-ups to fail. This in turn is a reason that many aspiring entrepreneurs are afraid to enter the playing field (Bocken and Snihur, 2020; Mikle, 2020).

Moreover, the AEC industry comprises of a hybrid of product and service industries. The result is a product, i.e., the building, bridge or house constructed, but many subcategories in the industry, especially the design components are service based. Thus, while the concept of lean start-ups and MVPs can be applied to construction start-ups, it is not applicable to design start-ups in the same industry. To ensure proper customer satisfaction, each design needs to begin with the most minimal initial design, which is then either approved or changes requested by the client. This continuous cycle ought to continue throughout the project. Hence, as a creative field, the design sector would find it difficult to go back and forth among their design concepts to accommodate the changes. Thus, the number of interactions between the designer and the client are reduced and the final design is a decision of the designer. Engineering designers do not necessarily face this issue, since they are a less customer facing role, which depends on the design of the architect. Hence, it is the role of the architect to ensure that the design is satisfying the customer while reducing the time and resources spent on developing design iterations up until the final design is agreed

upon. (Bondare *et al.*, 2017; Andrés-López, González-Requena and Sanz-Lobera, 2015; Pikas *et al.*, 2015; Jayasena and Weddikkara, 2012).

Further, a method of delivering the best value would be through codesign, which however could result in lower constructability of the project. (Combrinck and Porter, 2021; Trischler *et al.*, 2018; Kifokeris and Xenidis, 2017; Magnusson, Matthing and Kristensson, 2003) Hence, the lack of research on a structured method of planning and implementation of codesign in the service industry is imminent. Much more is the advantage of codesign in the AE industry. This study would help fill in the research gap of how client understanding/knowledge affects the impact of codesign on constructability of the project in AE industries. Further, there is a lack of research on lean methodologies in Sri Lankan context and any research available is focused on lean manufacturing or products rather than services or a hybrid context such as the AE industry. (Combrinck and Porter, 2021; Dietrich et al., 2017; Gupta, Sharma and Sunder, 2016; John M. Nicholas and Herman Steyn, 2021; Magnusson, Matthing and Kristensson, 2003; Mazlum and Pekeriçli, 2016; Senaratne and Wijesiri, 2008; Széchenyi István University, Kautz Gyula Economics Faculty and Ercsey, 2017; Weerasooriyan and Alwis, 2017; Yen, Teng and Tzeng, 2020)

1.3. Problem Statement

The lack of research on lean in the service sector is imminent. (Shepherd and Gruber, 2021) Further, the decisions which depend on the entrepreneur depends on their backgrounds, e.g., upbringing, education, and work exposure. In a start-up environment, the entrepreneur may be less aware and fear the elimination of waste due to inefficient identification of non-value adding activities. In the AE industry, entrepreneurs or practitioners need to be able to deliver the best value to their clients. The identification of the best value as perceived by the customer could be achieved by involving the client in the design process, i.e., codesign. However, previous studies suggest that collaborative design leads to lower feasibility of a project. (Magnusson, Matthing and Kristensson, (2003) as cited by Trischler et al., (2018)) There is a lack

of research on a how the different factors surrounding the client affects codesign, and how it in turn impacts the constructability of a project. (Bondare *et al.*, 2017; Gupta, Sharma and Sunder, 2016). Hence, this study researches the problem statement, "*the influence of codesign as a lean service approach on project feasibility among Sri Lankan architectural and engineering start-up practices with the effect of client knowledge as a mediating role*".

1.4. Research Objectives

- To evaluate the impact of codesign as a cocreation strategy on constructability of designs among Sri Lankan Architectural and Engineering design start-up practices.
- To examine how codesign as a cocreation strategy impacts client knowledge among Sri Lankan Architectural and Engineering design start-up practices.
- To examine the impact of client knowledge on constructability among Sri Lankan Architectural and Engineering design start-up practices.
- To evaluate whether client knowledge or understanding mediates the impact of codesign on constructability among Sri Lankan Architectural and Engineering design start-up practices.

1.5. Significance of the Research

This study would help fill the gap of knowledge of how client understanding/knowledge affects the impact of codesign on feasibility of the project in AE industries. Further, there is a lack of research on lean methodologies in Sri Lankan context and any research available is focused on lean manufacturing or products rather than services or hybrid industries. The identification of the best value as perceived by the customer could be achieved by involving the client in the design process, i.e., codesign. However, previous studies suggest that codesign leads to lower feasibility of a project. (Magnusson, Matthing and Kristensson, (2003) as cited by Trischler et al., (2018)) Moreover, there is a clear lack of research on a how the

different factors surrounding the client affect the dimensions of codesign. (Bondare *et al.*, 2017; Gupta, Sharma and Sunder, 2016).

Service industries such as the design industry benefit from lean services. The biggest challenge for service organisations is providing an experience to the customer which is non-parallel. Unlike a product which can be improved, the service sector has only one chance to please the customer. If businesses were to spend more effort on creating a better service, they face the risk that the customers may be looking for service that is quite different from your hypotheses. Thus, letting the customer service themselves seems to be an appropriate approach. However, how a designer is to integrate this into a creative project is unclear. (Bocken and Snihur, 2020; Sarkar, 2017; LaGanga, 2011; Ries, 2011)

2. LITERATURE REVIEW

2.1. Theory of Cocreation

Prahalad and Ramaswamy, (2004) defines cocreation is defined as collaboration of the customer and the business to create value, which allows customer innovation. Hence opposing the traditional approach of a business researching the market and deciding on products/services to be provided, cocreation promotes the customer servicing themselves. (Prahalad and Ramaswamy, 2004; Sarkar, 2017) Cocreation is a development of coproduction, within the product-based businesses. However, studies on cocreation tend to be more based on the service dominant logic (Grönroos and Voima, 2013).

Prahalad and Ramaswamy (2004) brought the DART concept, which defines the four main building blocks for effective value cocreation with the consumer. Since cocreation involves an external team, the communication between the firm and consumers/clients is of utmost importance. Hence Dialogue refers to interactive engagement between the consumer and the firm. However, this engagement and grasp of concepts are affected by the information that the consumer has access to. Thus, the

consumer's input into the cocreation process depends upon the access to information that the firm has. Transparency therefore is the open access of all information to the consumer. In traditional firms, information which is only known by the organisation is seen as an advantage. Firms and marketers have been blamed for manipulating customers by retaining false transparency. Along with the emergence of big data, this seems to have become an even worse ethical concern. Thus, cocreation argues that transparency provides much better advantage to the firm, since the needs of the external team maybe different than perceived by the firm. Hence, the transparency would allow the consumers to provide their feedback and improve engagement. Thus, open access and transparency leads to better dialogue, which in turn improves the value creation process. The access, transparency and dialogue allow the consumer to make a clear risk assessment. Thus, the consumer makes a clear decision of whether the process is creating the value they desire. This could of course lead to a decision where the consumer may choose to provide their involvement to a different firm, a competitor. (Ansari and Gupta, 2021; Grönroos and Voima, 2013; Prahalad and Ramaswamy, 2004, 2003; Wertenbroch, 2016; Xie et al., 2016)

However, this understanding of risk assessment, is highly personalised. Hence the involvement of lead consumers in the improvement of products/services. The process of mass customisation is clearly firm centred and thrives on the current dominant logic. Hence, personalised cocreation means that the consumer has control over the interaction and demands. This also challenges the top-down approach in firms. Cocreation is not mere customisation. It is the sharing of control with consumers to deliver value that is desired by the consumer, thus removing all market manipulation in the process. (Ansari and Gupta, 2021; Grönroos and Voima, 2013; Prahalad and Ramaswamy, 2004, 2003; Wertenbroch, 2016)

2.2. Lean Principles: a Relationship with Cocreation

This concept of the customer servicing themselves is a of lean principles which revolves around delivering optimal value to the customer and eliminating waste.

(Sarkar, 2017) Start-ups are often unaware of their customers' needs. In other words, start-ups have a harder time delivering better value to customers. Lean service innovation refers to iterative involvement of the customer via experimenting throughout the process of coming up with the best value deliverable. It is a development of the service-dominant (SD) logic. Customers being engaged from the beginning of the process provides better value delivery since the business is not making assumptions on customer needs. Cocreation is usually discussed as a separate topic which includes the customer during the process instead of involving the customer in the approaches for handling the complete process. (Bocken and Snihur, 2020; Lichtenthaler, 2020; Mazlum and Pekeriçli, 2016; Ojasalo and Ojasalo, 2018; Ries, 2011)

The lean service innovation model proposed by Ojasalo and Ojasalo (2018), defines the preliminary stage of delivering value as cocreation to understand in depth about the customer. The paper then goes on to describe the latter stages as preliminary needs definition, proposal of solutions and developing a minimum viable product, service or prototype (MVP/MVS). The MVP/MVS is then launched to real customers and their experience with it is evaluated to decide whether full-scale implementation is feasible or if the product/service needs to be abandoned. Bringing this into the infrastructure design industry would mean involving the client in the design stage and in defining how the process continues from there. (Karpen, Bove and Lukas, 2012; Kreuzer, Schäfer and Aschbacher, n.d.; Ojasalo and Ojasalo, 2018; Ozkeser, 2018; Prahalad and Ramaswamy, 2004; Széchenyi István University, Kautz Gyula Economics Faculty and Ercsey, 2017; Vaajakallio and Mattelmäki, 2014; Yen, Teng and Tzeng, 2020)

2.3. Codesign as a Cocreation Strategy

Sanders and Stappers (2008) defines codesign as the act of designers and non-designers coming together to collaborate creativity in the development of designs, as a branch of cocreation, which they define as collective creativity. Hence, in more

design-based industries, such as architecture, engineering, graphic design etc, the collaboration of parties can be worded as codesign. The Architectural and Engineering design industry is a combination of architecture and engineering and hence, cocreation in these industries becomes codesign. Codesign is thus a collaborative design process. (Combrinck and Porter, 2021; Mattelmäki and Visser, 2011; Prahalad and Ramaswamy, 2003; Sanders and Stappers, 2008; Vaajakallio and Mattelmäki, 2014). Vaajakallio and Mattelmäki (2014) further states that codesign is supported by the belief that all individuals can contribute to the design process.

The DART dimensions (Prahalad and Ramaswamy, 2003) of codesign can be approached in a more specific manner in terms of the form of facilitation, the time span of the engagement, the phases of the design process, the level of the contributions from users and other stakeholders and the application of design tools. The form of facilitation in the codesign of an Architectural or Engineering project would include the mode of communication, the place of meetings etc. Clearly, the amount of time given to the client to be involved in the design process would affect the transparency and access to information of the design process. Further, an infrastructure design involves multiple stages of design, starting from architectural designs to architectural detailing and moving on into the engineering design stages of the project. The engineering design further involves stages of various types of designs including the design of the main structure (structural design), the ground related designs on the area of construction (geotechnical design) as well as the finishing design, which is the covering of any awkward points in the structure to be more accessible too occupants. Of course, depending on the type of infrastructure being designed and its location, consideration of earthquakes, water bodies etc are also involved and are mostly unique to each project. Hence where the client needs to be involved in the stages of this process is also affects the codesign process and hence, the engagement of the client is also affected. Moreover, the use and application of various design tools such as BIM would also affect the codesign process. (Mattelmäki and Visser (2011) as cited by Trischler et al., (2018); Combrinck and Porter, 2021;

Goel, 2012; Gray and Hughes, 2001; John M. Nicholas and Herman Steyn, 2021; Prahalad and Ramaswamy, 2004; Sanders and Stappers, 2008)

2.4. Project Feasibility

According to Mesly (2017), a project is not considered to be feasible if the positive factors supporting a project are less than the negative factors that are against the project. Feasibility is also used to forecast the success of a project. (Cartlidge, 2020) Before a project moves into the construction or execution stage, a feasibility study of both the financial and technical concepts is undertaken. The feasibility study of an ID includes costing, accommodation, value an9d risk assessment, sensitivity analysis, site assessments (location of construction), health and safety impact, environmental impacts, procurement, and the possibility of including various BIM systems in the design process. The feasibility of a project is heavily impacted by changes to costing. Hence the probability of 1% or more occurrence of costing changes reduces the feasibility of the project. Hence, funding as well as inflation, material availability etc affect the project feasibility. Hence, the client's needs that need to be fulfilled via the project are the main drivers of feasibility in a project. (Cartlidge, 2020)

2.5. Constructability: Technical Feasibility

Bea (2005) defines that a design made considering constructability should enable construction, taking into consideration, employee qualifications, capabilities, safety, environmental impacts, and interfaces between the equipment and workers. Further it consists of operational performance evaluation, value engineering, knowledge management, cost/benefit analysis, quality management and building performance framework, i.e., spatial performance, acoustic performance, visual performance, indoor atmosphere, thermal performance, and building integrity analysis. Hence, constructability is a technical form of feasibility. (Alshawi and Underwood, 1996; Green, 1990; Haider, 2009; Ireland, 2006; Low et al., 2008; Rezgui et al., 2010;

Russell et al., 1994; Rwelamila and Savile, 1994; Tatum, 1990; Tatum, 1993 as cited by Kifokeris and Xenidis, 2017)

2.6. Operational Performance Evaluation

Operational performance is a measure of how effective the chosen structure or approach to the project is. Based on the type of infrastructure being designed, this would change. E.g., whether it would become a domestic residence or if would become a commercial property, the exact end use, such as school buildings, auditoriums, houses etc. Hence out of the numerous structural options, the most viable one is chosen. This choice is based on the understanding of the technical personnel on the project team (engineers and architect). The client is rarely involved in such discussions, unless the requirements of the client cannot be met technically under the budgetary constraints. (Cartlidge, 2020; Fewings, 2019; Kifokeris and Xenidis, 2017; Mesly, 2017; Goel, 2012; Bea, 2005; Ford *et al.*, 2004; Gray and Hughes, 2001; Ireland, 1985)

2.7. Value Engineering

Value engineering (VE) is an analysis of value that can be delivered via a project. It includes optimising the value that is created by a project and is also sometimes known as value management, but the term value engineering is more common in the construction industry. Through this process, firms improve quality, performance and value created and reduces costs, thus increasing profits. VE becomes harder when the client is more actively involved in the project rather than proactively or as a third party. The collaborative design process means that clients would provide their needs in the micro scale in design decisions. Overall, since the knowledge possessed by the project members are not possessed by the client, a clash of opinions becomes possible. Further in trying to deliver the best value, the knowledge transfer needs to be efficient, to allow clear understanding in all parties and improve value creation,

hence the importance of knowledge management (KM). (*SAVE International*., n.d.; Wao, 2015)

2.8. Knowledge Management (KM)

The construction industry is a knowledge intensive industry. Hence, managing the flow of knowledge among the project teams is important. Knowledge, which, is tacit (personalised knowledge) and explicit (easily available to view) needs to be transferred between individuals. Socialisation (tacit to tacit), externalisation (tacit to explicit), internalisation (explicit to tacit) and combination (explicit to explicit) are the methods of knowledge transfer. Hence, the knowledge gained by the architect, engineer or even the client through their own personal experiences are highly individualised and are not freely available to others. Therefore, the understanding of one person differs from another. Socialisation helps spread this tacit knowledge through open discussions between individuals. Further, the documentation or publication of tacit knowledge allows others to access said knowledge and thus improves the transfer of knowledge, which is externalisation. Utilising published or readily available knowledge and personalising it to oneself, to match the project requirements at hand is defined as internalisation, and the addition of new knowledge to existing published information is called combination. These methods, if utilised properly helps all project participants understand the project constraints and practical implications.(Cartlidge, 2020; Bettiga and Ciccullo, 2018; Anumba, Egbu and Carrillo, 2008; Prahalad and Ramaswamy, 2003; Nonaka *et al.*, 1995)

2.9. Cost/Benefit Analysis (CBA)

Cost/benefit analysis (CBA) is argued to be a tool to guide decision making. It provides a guide for the benefit, or use generated out of a decision in comparison to the cost incurred. It is a form of value evaluation which is quantitative and measurable. CBA can be used to endure that the project is delivering optimal value and that the client is given a fair deal for their investments (Mishan and Quah, 2020).

2.10. Quality Management (QM)

Quality management (QM) in construction projects comes in various stages and forms. It is not only the quality of materials and final infrastructure constructed but is also the quality of the total flow of the project, timely completion, quality of designs, appearance etc. Usual quality control in this industry includes complying to quality standards defined by a regulating body. Quality assessment comprises of several parameters which are measured in assessing the overall quality, i.e., cost of poor quality (customer dissatisfaction of value delivered or loss generated), firm's position in the market (reputation of the firm mainly based off client reviews and successful project completions and optimal value delivery as perceived by the client), culture of quality within the firm or the company's perception of quality, the flow of the quality management system being used and critical self-assessment of the firm's value delivery capabilities (Rumane, 2017).

2.11. Building Performance Framework

The performance of an infrastructure constructed is measured since its health, safety, security, functionality, efficiency, workflow, psychological impact, societal impact and the cultural or aesthetic view provided. The BPE (Building performance evaluation) framework defines the parameters as reviews to be conducted during the project, namely, effectiveness review, market review, post occupancy evaluation, program review and a design review. The design review assesses the effectiveness of the designs to meet the optimal value delivery. (Preiser, W.F.E. and Vischer,J. (eds.), 2005)

2.12. Constructability and Codesign

Project feasibility, which is usually undertaken in the initial stages of a project, assumes that the knowledgeable project team ensures constructability within standards of the scope. The client's needs are identified in the most preliminary stages and are thus an interpretation of their descriptions or examples etc. Hence, once the

concept of codesign is brought into the design process, the client's needs are continuously identified within the design process. The involvement of the client as a cocreation approach in the design process changes the feasibility of the project. With new product developments, for example, the ideas generated by the customers which may not be completely feasible at once need to be filtered, and a feasibility study carried out on the technical feasibility. However, in the case of codesign, which is client engagement throughout the design process, the feasibility would be impacted greatly since the design process in ID is usually dominated by experts. These experts can ensure feasible designs. The involvement of the client changes this and is also a possible cause for disagreements. Thus, the feasibility/constructability of final designs would need to be reassessed. Hence codesign would have a significant impact on the constructability of the designs. (Bettiga and Ciccullo, 2018; Cartlidge, 2020; Combrinck and Porter, 2021; Dietrich et al., 2017 Fewings, 2019; Mesly, 2017; Vaajakallio and Mattelmäki, 2014)

2.13. Customer Resources

Wang and Xu (2002) as cited by Xiao, Ma and Li (2020) states that customers can we viewed as assets to companies to generate value, and from a customer perspective, customers have resources which they do not know or have the exposure to utilise productively alone. Further, Rodie and Susan (2000) as cited by Xiao, Ma and Li (2020) defines customer resources as emotion, physical strength and intelligence. Hence during a collaborative value creation process, both companies and customers would invest knowledge, financial and social resources they have according to Wang (2005) as cited by Xiao, Ma and Li (2020). He and Tu (2012) as cited by Xiao, Ma and Li (2020) also categorises resources of the customer as cognitive, financial and time. Further, Plé (2016) defines customer resources as informational, emotional, physical, financial, time-based, behavioural, relationships based, societal, cultural, role based, capability based and customers' wishes based. Xiao, Ma and Li (2020) goes on to categorise customer resources as human (knowledge, skills, exposure,

experience etc), psychological ability to promote value creation. relationship building and financial assets owned by the customer.

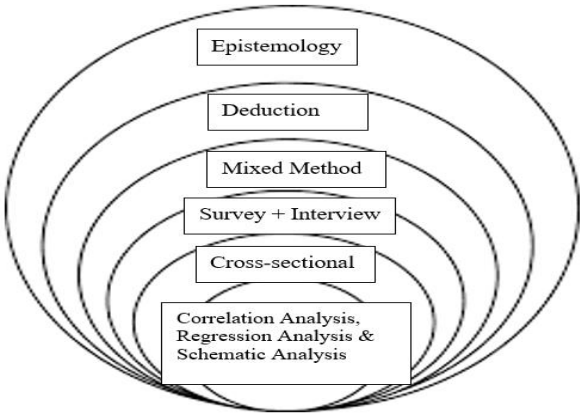
Xiao, Ma and Li (2020) argue that customer resources in value cocreation are the abilities possessed or circumstances utilized by the customer. Wu and Chen (2012) as cited by Xiao, Ma and Li (2020) identified the impact of customer resources in the cocreation process. Hence, the resources that customers possess should complement that of the employees engaging in the project from the firm for cocreation to be value adding. Brucks (1985) proposes that confidence plays a key role in the customer's knowledge. Since value perception is unique to everyone, customer knowledge would play a role in the perception of value as well as the possibility of said value creation. (Zhang et al., (2005) as cited by Xiao, Ma and Li (2020)) Hence, during the cocreation process, interaction with the customer is key to better engagement, which builds customer confidence and hence brings out the optimal value improvement that the customer can provide through their resources, i.e., knowledge. (Kelly, Donnelly and Skinner, 1990; Plé, 2016; Xiao, Ma and Li, 2020). Hence co creation has a direct relationship with customer knowledge, and cocreation depends on the ability of the customer to process information and engage in deep conversations leading to more complex interactions. Moreover, since a customer's perception defines value, their understanding or knowledge of a project and its constraints would directly impact the constructability of a project. Hence, customer knowledge also has a direct impact on the constructability of a project that is being cocreated. (Xiao, Ma and Li, 2020)

3. METHODOLOGY

This research follows an epistemological philosophy since many relationships being researched have previous studies in various other fields and approaches. Hence, the assumptions on knowledge can be justified with sufficient previous research. Therefore, a deductive approach seems feasible, since data can be found based off existing research theories. However, in this research, an additional component of research has been followed, through in-depth interviews to validate the findings of

the study. Hence the study is primarily quantitative, utilizing questionnaire surveys and uses a concurrent mixed method approach to validate the findings. (Saunders, 2019; Tashakkori and Teddlie, 2010).

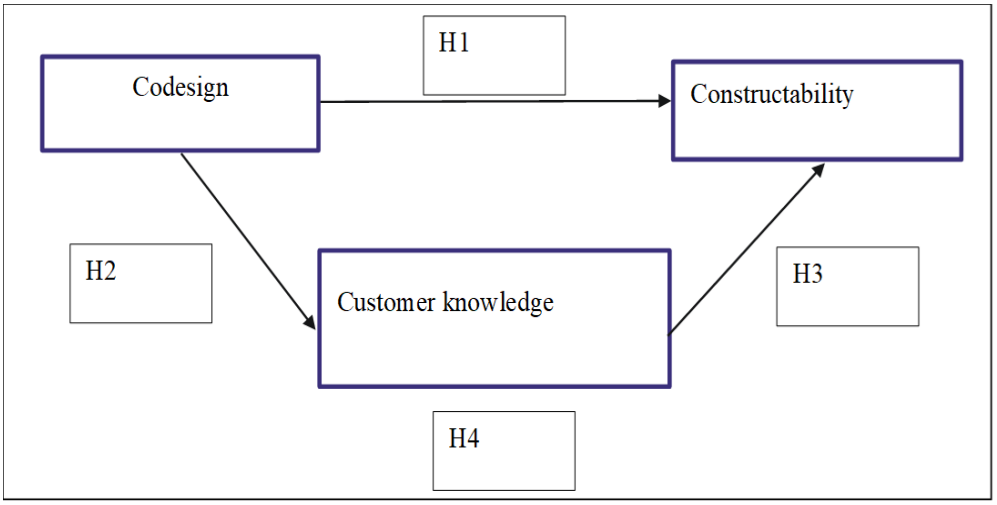
Figure 1: Research Onion for this research



(Source: Saunders, 2019; Tashakkori and Teddlie, 2010)

3.1. Conceptual Framework

Figure 2. Conceptual framework



Project feasibility, which is usually undertaken in the initial stages of a project, assumes that the knowledgeable project team ensures constructability within standards of the scope. The client's needs are identified in the most preliminary stages and are thus an interpretation of their descriptions or examples etc. Hence, once the concept of codesign is brought into the design process, the client's needs are continuously identified within the design process. The involvement of the client as a cocreation approach in the design process changes the feasibility of the project. With new product developments, for example, the ideas generated by the customers which may not be completely feasible at once need to be filtered, and a feasibility study carried out on the technical feasibility. However, in the case of codesign, which is client engagement throughout the design process, the feasibility would be impacted greatly since the design process in ID is usually dominated by experts. These experts can ensure feasible designs. The involvement of the client changes this and is also a possible cause for disagreements. Thus, the feasibility/constructability of final designs would need to be reassessed. Hence codesign would have a significant impact on the constructability of the designs. (Bettiga and Ciccullo, 2018; Cartlidge, 2020; Combrinck and Porter, 2021; Dietrich et al., 2017 Fewings, 2019; Mesly, 2017; Vaajakallio and Mattelmäki, 2014)

Customer cocreation success depends on the value perception of the customer. Customer knowledge and experience are dominant factors that affect the value creation process. While intangible resources such as relationship building certainly support the value creation, they are not dominating factors. Further, in depth interaction between the firm and customers helps cocreation. And for this to happen, the customer ought to have sufficient knowledge or understanding to engage in these serious activities. Hence co creation has a direct relationship with customer knowledge, and cocreation depends on the ability of the customer to process information and engage in deep conversations leading to more complex interactions. Moreover, since a customer's perception defines value, their understanding or knowledge of a project and its constraints would directly impact the constructability

of a project. Hence, customer knowledge also has a direct impact on the constructability of a project that is being cocreated. (Xiao, Ma and Li, 2020)

3.2. Hypotheses

H1: Codesign as a cocreation strategy has a significant impact on constructability among Sri Lankan Architectural and Engineering design start-up practices

In the case of codesign, which is client engagement throughout the design process, the constructability would be impacted greatly since the design process in ID is usually dominated by experts, who know the constraints and implications. (Trischler *et al.*, 2018; Mattelmäki and Visser, 2011; as cited by Prahalad and Ramaswamy, (2004))

H2: Codesign as a cocreation strategy has a significant impact on client knowledge among Sri Lankan Architectural and Engineering design start-up practices

Codesign or cocreation processes are collaborative. Hence, the client would actively be utilising information available to the firm to perceive value. The client's knowledge is therefore affected by various forms of knowledge transfer within the project team, such as socialisation and internalisation. (Anumba, Egbu and Carrillo, 2008; Combrinck and Porter, 2021; Mattelmäki and Visser, 2011; Nonaka et al., 1995; Prahalad and Ramaswamy, 2004)

H3: Client knowledge has a significant impact on constructability among Sri Lankan Architectural and Engineering design start-up practices

Since a customer's perception defines value, their understanding or knowledge of a project and its constraints would directly impact the constructability of a project. Hence, customer knowledge also has a direct impact on the constructability of a project that is being cocreated. (Xiao, Ma and Li, 2020)

H4: Client knowledge mediates the impact of codesign on constructability among Sri Lankan Architectural and Engineering start-up practices

From previous literature it seems that client knowledge is related to both variables, codesign and constructability. Therefore, client knowledge is explored as a mediating factor in this research according to Brucks (1985) and Zhang et al., (2005) as cited by Xiao, Ma and Li (2020); Kelly, Donnelly and Skinner (1990); Plé (2016); and Xiao, Ma and Li (2020).

3.3. Operationalisation of Variables

Table 1 Variable Operationalisation Table

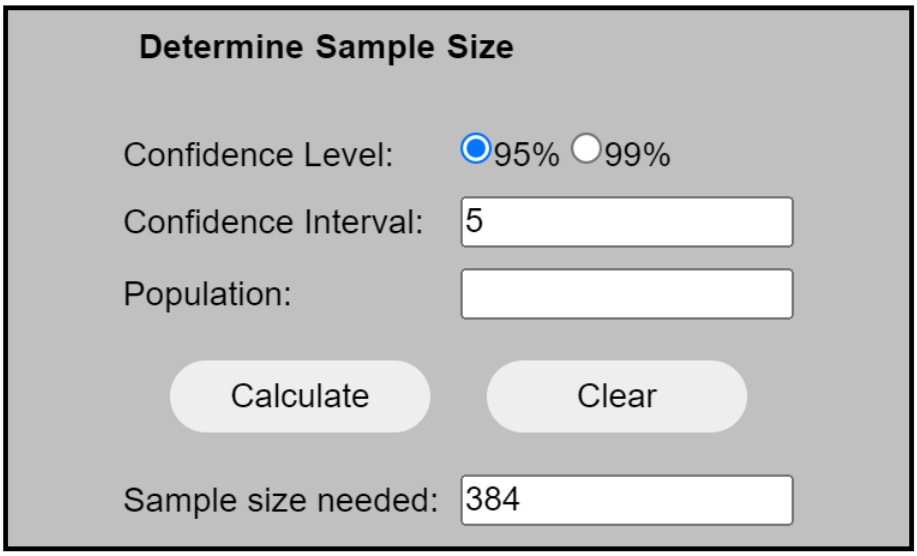
Concept	Variable	Measures/Indicators	Source
Cocreation	Codesign Codesign is a branch of cocreation used in design based industries which assumes that everyone is able to contribute to a design through creativity and knowledge. (Combrinck and Porter, 2021; Dietrich *et al.*, 2017; Prahalad and Ramaswamy, 2003)	Form of facilitation Time of engagement Frequency of engagement Access to information Transparency of information Risk assessment	Mattelmäki and Visser (2011) as cited by Trischler et al., (2018); Prahalad and Ramaswamy, (2004)
Project Feasibility	Constructability Constructability is defined as the evaluation of parameters involved and practical implications incurred in making a project a success. (Bea, 2005)	operational performance value engineering knowledge management cost/benefit analysis quality management building performance framework	Alshawi and Underwood, (1996); Green, (1990); Haider, (2009); Ireland, (2006; Low et al., 2008; Rezgui et al., 2010; Russell et al., 1994; Rwelamila and Savile, 1994; Tatum, 1990; Tatum, 1993 as cited by Kifokeris and Xenidis, 2017.
Customer Resources	Client knowledge	Experience Confidence Cognitive ability	Brucks (1985); Zhang et al., (2005) as cited by Xiao, Ma and Li (2020); Kelly, Donnelly and Skinner (1990); Plé (2016); Xiao, Ma and Li (2020)

3.4. Sampling Method & Justification

The sampling method utilised will be convenient sampling. Respondents of this research are experts or upcoming experts who are currently practicing on their own. Hence, the knowledge level of this population is quite equally distributed. Further, a proper sample size is not listed for the number of start-up practices in Sri Lanka. Many start-up practices are individual practices, and it is not possible to determine which of the list of engineers and architects listed are practicing on their own or in their own start-up practice. Further, although the sample size on the calculator is shown as 384, this is only because the population is unknown. Hence, a qualifying question about their experience was added to the questionnaire. (Stratton, 2021; Collins, 2010; Tashakkori and Teddlie, 2010; Morse, 1994)

Hence given below is the sample size using a sample size calculator for an unknown population size for the quantitative component, i.e., questionnaire surveys. Since the population involved is highly knowledgeable and actively involved with technology, a Google form will be used to distribute the questionnaire.

Figure 3: Sample size calculator



(Source: https://surveysystem.com/sscalc.htm*)*

For the cross validation of the findings from the main questionnaire collection, an additional component of interviews was undertaken among management and marketing experts (consultants). A total of 6 interviews were conducted in line with Morse (1994). The smaller sample size was to allow deeper conversation on the issues with each respondent and grasp better input from each, since the respondents would have a lot of experiences and information to share. (Stratton, 2021; Saunders, 2019; Collins, 2010; Tashakkori and Teddlie, 2010)

3.5. Data Analysis

This research utilises descriptive statistical methods for analysis of the main quantitative data. Correlation analysis was used to verify the variable relationships of codesign, and constructability and regression analysis was used to test the mediating factor of client knowledge. SPSS v23 was used as the supportive software to analyse the data. The Likert scale was utilised in the questionnaires as a guide of the responses. (Rinker, 2014)

3.6. Ethics

No serious ethical dilemma was found for the research based on the sample and population. The ethics form is attached in the appendix section of the report.

3.7. Questionnaire Description

The questionnaires were developed based on the variable operationalisation table and the main questions measuring each variable were all on the Likert scale and would all in as ordinal data. Hence for data analysis, the mean values were calculated to convert them into scale variables. Two qualifying questions assessed the viability of responses and were both yes/no questions and the response no would then trigger a form submission instead of continuing to the rest of the questions. This helped to keep the data set cleaner.

Figure 4: Qualifying questions asked on questionnaire.

5) Out of the experience indicated above, were you ever, or are you practicing individual or small team start-up project designs, such as building design, interior design, etc? *

- Yes
- No

6) Please indicate whether you have obtained enough training, education or expertise and exposed to design related functions to be performed in your job capacity. *

- Yes
- No

4. DATA ANALYSIS AND PRESENTATION OF FINDINGS

This section presents the analyses carried out on the sample data, the preliminary tests to determine reliability, validity, and sample adequacy as well as major findings on each variable. It also includes the results of hypotheses testing using Pearson correlation and regression analysis. The mediator test was done using both the Sobel test and Bootstrapping on SPSS and the results are also reported. In addition, the findings from the questionnaire distribution were validated through several interviews and the data is analysed using Thematic analysis.

5. Analysis of Sample Profile Data

5.1. Age

Table 2: Age analysis

		Frequency	Percentage
Valid	18-30	65	65.0
	31-40	29	29.0
	41-50	4	4.0
	51 and above	2	2.0
	Total	100	100.0

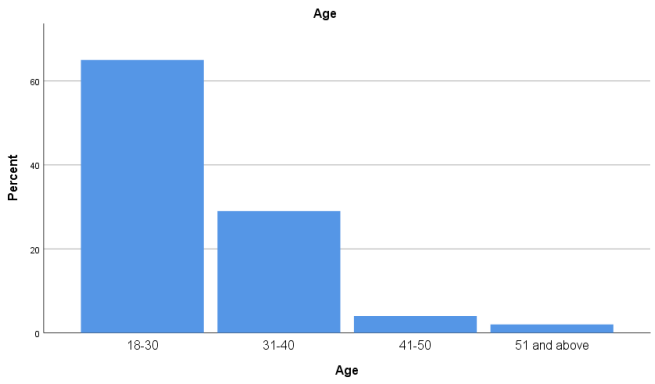
Source: SPSS Data 2021/2022

Table 3 Age statistics

		Age
N	Valid	100
	Missing	0
Median		18-30
Mode		18-30

Source: SPSS Data 2021/2022

Figure 5: Age representation



Source: SPSS Data 2021/2022

Based on the data from Table 2 and

Figure , a majority of the sample is represented by young individuals ages 18-30, which is 65% of the whole sample. All other categories total to only 35%. Thus, the research findings are mainly biased for the perspective of the youth or young adults.

5.2. Gender

Table 4: Gender analysis

		Frequency	Percent
Valid	Female	30	30.0
	Male	70	70.0
	Total	100	100.0

Source: SPSS Data 2021/2022

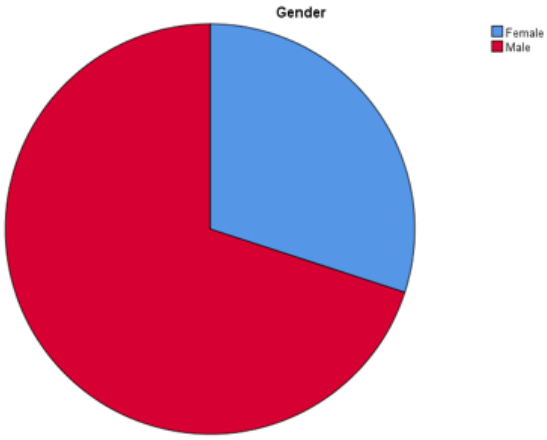
Table 5 Gender statistics

Gender		
N	Valid	100
	Missing	0
Mode		Male

Source: SPSS Data 2021/2022

Based on the data from Table 4 and Figure 1**Error! Reference source not found.**, a majority of the sample is represented by males which is 70% of the whole sample. Females total to only 30%. Thus, the research findings are mainly biased for the male perspective.

Figure 1 Gender percentage



(Source: SPSS Data 2021/2022)

5.3. Education

Table 6 Education analysis

		Frequency	Percent
Valid	Undergraduate/Bachelors	39	39.0
	Postgraduate/Masters	29	29.0
	Chartered Architect/Engineer	27	27.0
	Diploma or HND	5	5.0
	Total	100	100.0

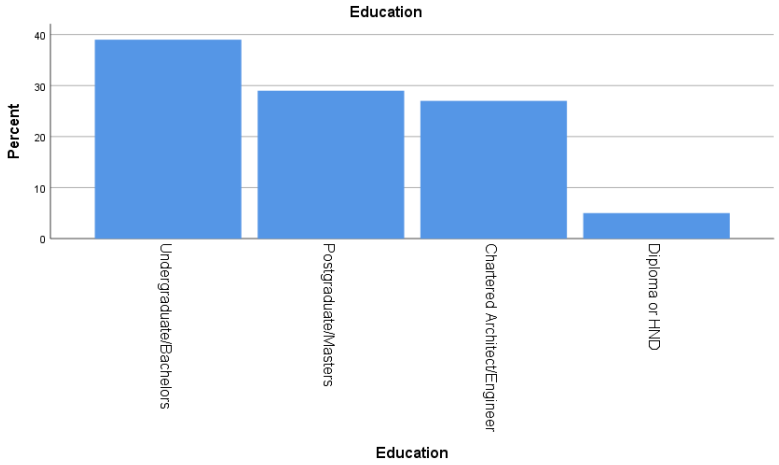
Source: SPSS Data 2021/2022

Table 7 Education statistics

		Education
N	Valid	100
	Missing	0
Median		Postgraduate/Masters
Mode		Undergraduate/Bachelors

Source: SPSS Data 2021/2022

Figure 2 Education representation



(Source: SPSS Data 2021/2022)

Based on the data from Table 6 and Figure 2, a majority of the sample is represented by bachelor's degree holders, which is 39% of the whole sample. Master's degree holders also have a considerable representation of 29%. Thus, the research findings are mainly biased for the bachelor's and master's degree holder perspective.

5.4. Experience

Table 8 Experience analysis

		Frequency	Percent
Valid	1 year or less	19	19.0
	A little more than 1year	12	12.0
	2-4 years	30	30.0
	5-8years	21	21.0
	9-12 years	11	11.0
	13+years	7	7.0
	Total	100	100.0

Source: SPSS Data 2021/2022

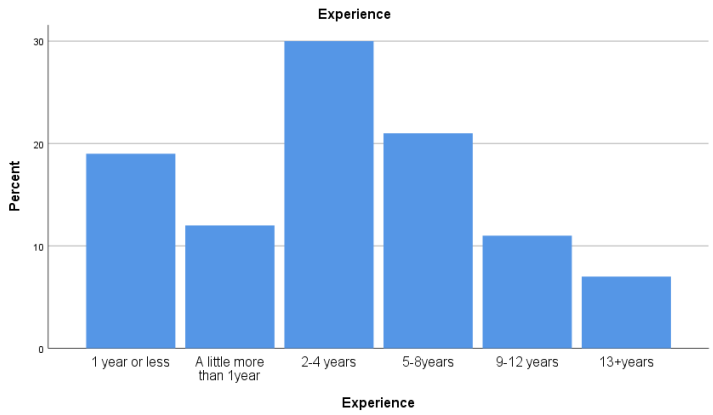
Table 9 Experience statistics

		Experience
N	Valid	100
	Missing	0
Median		2-4 years
Mode		2-4 years

Source: SPSS Data 2021/2022

Based on Figure 8 and Table 8, a majority of the sample is represented by individuals with 2-4years of experience, which is 30% of the whole sample. Thus, the research findings are mainly biased for the 2-4year experienced perspective.

Figure 3 Experience representation



(Source: SPSS Data 2021/2022

5.5. Descriptive Data Analysis

Mean Value Analysis of Codesign

Table 10 Analysis on Codesign

Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral; 4 – Disagree & 5 – strongly disagree in SPSS analysis.

	N		
	Valid	Missing	Mean
Form of facilitation	100	0	1.59
Time of engagement	100	0	1.70
Frequency of engagement	100	0	2.13
Access to information	100	0	1.77
Transparency of information	100	0	1.88
Client's risk assessment	100	0	1.86

Overall Mean of Codesign = 1.82

(Source: SPSS Data 2021/2022)

Form of facilitation is the most important factor since it has the mean value closest to the strongly agree point on the Likert scale. In the analysis, number 1 was assigned to strongly agree and number 5 to strongly disagree. Frequency of engagement has the mean closest to the neutral point, meaning that it is one of the least important factors. However, all other factors have the same mode, meaning they are all agreed upon to be quite important but not as important as form of facilitation.

5.6. Mean Value Analysis of Constructability

Table 11: Analysis on Constructability

Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral; 4 – Disagree & 5 – strongly disagree in SPSS analysis.

	N		Mean
	Valid	Missing	
Operational performance	100	0	1.87
Value engineering	100	0	1.78
Knowledge management	100	0	1.61
Cost/benefit analysis	100	0	1.70
Quality management	100	0	1.68
Building performance framework	100	0	1.68

Overall Mean of Constructability = 1.70

Source: SPSS Data 2021/2022

Knowledge management is the most important factor since it has the mean value closest to the strongly agree point on the Likert scale. In the analysis, number 1 was assigned to strongly agree and number 5 to strongly disagree. Quality management has the next most significant mean, followed by the building performance framework, with slight differences.

5.7. Mean Value Analysis of Client Knowledge

Table 12 Analysis on Client knowledge

Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral;

4 – Disagree & 5 – strongly disagree in SPSS analysis.

	N		
	Valid	Missing	Mean
Cognitive skill	100	0	2.12
Confidence	100	0	2.10
Experience	100	0	2.08

Overall Mean of Client Knowledge = 2.10

Source: SPSS Data 2021/2022

Experience is the most important factor since it has the mean value closest to the strongly agree point on the Likert scale. In the analysis, number 1 was assigned to strongly agree and number 5 to strongly disagree. All other factors had similar mean values, but cognitive skill has the mean furthest from the strongly agree point.

5.8. Preparation of Data Set for Analysis

Outliers were not excluded from the data set since removal would change the actual truth of the situation. The size of the data set being small, since the number of start-up design practices in Sri Lanka are limited. Further the response rate was quite low even with the convenience sampling method. This shows that random sampling would have produced even lower responses. Questionnaire that stopped at qualifying questions were also removed for smooth analysis of data since they do not fall in as the sample. Given the sample size, there did not seem to be any erroneous responses.

The sample size which was shown as 384 in the calculator seems to be quite unrealistic. Further due to not having a listed population of individual practitioners and start-ups in Sri Lanka in the infrastructure design/architectural and engineering design industry. A total of 113 responses were received and out of it, only 100 passed

the qualifying question. 13 questionnaires were removed in total. Hence, the convenience sampling method has proven to be useful in ensuring more responses from qualifying respondents. Further, according to Roscoe (1975) as cited by Sekaran and Bougie (2016), the sample size needs to be at least 10 times larger than the number of variables. The number of variables in this research are three, codesign as the independent variable, constructability as the dependent variable and client knowledge explored as a mediator. Hence, the sample size obtained is larger than 30. Gorsuch (1983) defines a sample size of at least 100 for factor analysis. So does Kline (1994).

5.9. Reporting Reliability of Data Set

Table 13 Cronbach's Alpha values

Variable Type	**Variable Name**	**Number of Items**	**Cronbach Alpha Value**
Independent	Codesign	6	0.768
Dependent	Constructability	7	0.834
Mediator	Client Knowledge/Understanding	26	0.957

Source: SPSS Data 2021/2022

The Cronbach alpha values were all greater than 0.7 showing good reliability of the data set. (Pallant, 2020; Hair *et al.*, 2019; Sekaran and Bougie, 2016; Urbano, 2013)

5.10. Reporting Validity

Table 14 KMO Value for sample adequacy

Variable Type	**Variable Name**	**KMO Value**
Independent	Codesign	0.708
Dependent	Constructability	0.807
Mediator	Client Knowledge/Understanding	0.888

Source: SPSS Data 2021/2022

KMO greater than 0.6 is mentioned to be the minimum for factor analysis. The closer the KMO value is to 1, the validity is greater. Therefore, constructability and client knowledge have greater validity than codesign, but the difference is only 0.1. Therefore, the sample is adequate. (Pallant, 2020; Hair *et al.*, 2019; Sekaran and Bougie, 2016; Kline, 1994; Gorsuch, 1983).

Table 15: AVE Analysis for validity

Constructability	**N**	**4**
	Average Variance Extracted (AVE)	0.658431
	Composite Reliability	0.833822
Client Knowledge/Understanding	**N**	**7**
	Average Variance Extracted (AVE)	0.708166
	Composite Reliability	0.877147

Source: SPSS Data 2021/2022

The Average variance extracted is greater than 0.5 and is hence acceptable as valid data for further analysis (Fornell and Larcker, 1981).

5.11. Normality of Data Set

Table 16 Skewness and Kurtosis

		Statistic	Std. Error
Codesign	Skewness	.599	.241
	Kurtosis	1.475	.478
Constructability	Skewness	.705	.241
	Kurtosis	1.784	.478
Client Knowledge/Understanding	Skewness	.216	.241
	Kurtosis	.250	.478

Source: SPSS Data 2021/2022

A skewness between -1 to +1 is stated to be acceptable according to Hair *et al.* (2019). Urbano (2013) also states that a skewness of -3 to +3 is also acceptable and that kurtosis should lie between -10 to +10. A general principle is that skewness and kurtosis closer to zero shows better normality. The skewness values seem to be quite close to zero in this case. However, the Kurtosis does tend to pass 1. But overall, they both lie within the acceptable range. (Pallant, 2020; Hair *et al.*, 2019; Urbano, 2013)

Table 17 Statistical values

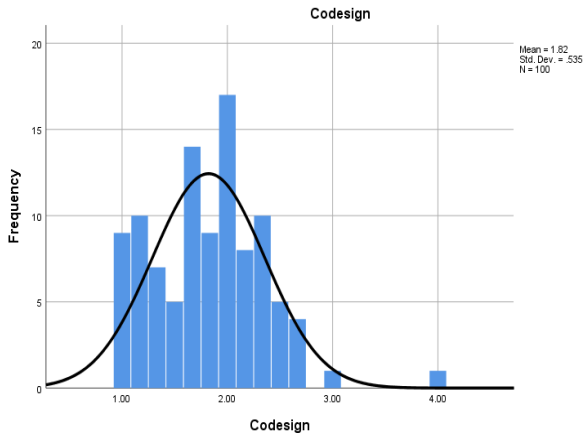
Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral; 4 – Disagree & 5 – strongly disagree in SPSS analysis.

		Codesign	Constructability	Client Knowledge
N	Valid	100	100	100
	Missing	0	0	0
Mean		1.8217	1.7043	2.0912
Median		1.8333	1.7143	2.0769
Mode		2.00	2.00	2.00

Source: SPSS Data 2021/2022

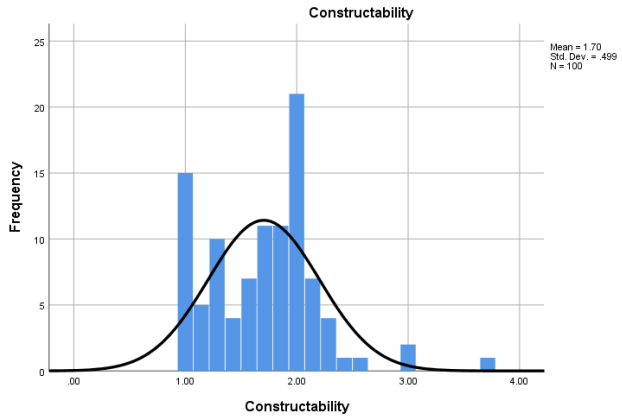
The histograms show that client knowledge has good normal distribution, while codesign and constructability variables tend to be more towards one end.

Figure 4 Histogram of Codesign



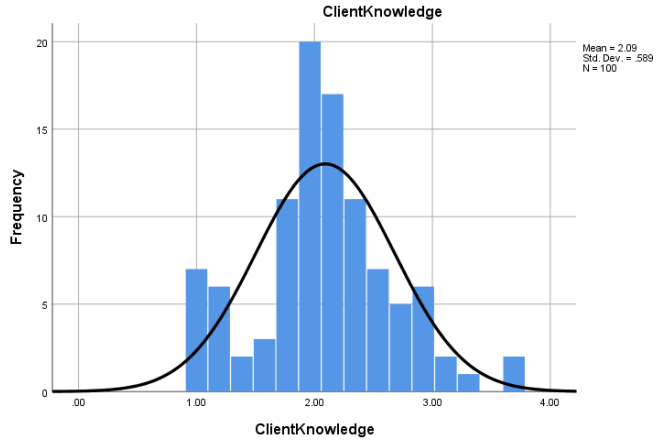
(Source: SPSS Data 2021/2022)

Figure 5 Histogram of Constructability



(Source: SPSS Data 2021/2022)

Figure 6 Histogram of Client Knowledge



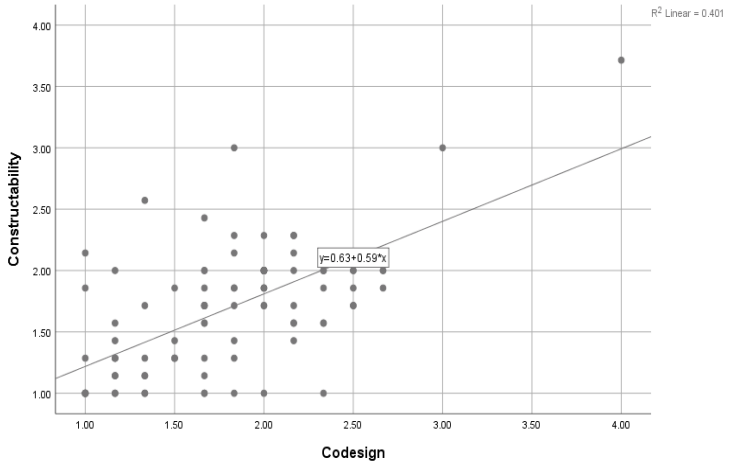
(Source: SPSS Data 2021/2022)

5.12. Testing Hypotheses

Given the results of the reliability, validity and normality tests, the research is permitted to conduct hypotheses testing.

H1: Codesign as a cocreation strategy has a significant impact on constructability among Sri Lankan Architectural and Engineering design start-up practices.

Figure 7 Scatter plot of Codesign vs Constructability



Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral;

4 – Disagree & 5 – strongly disagree in SPSS analysis.

(Source: SPSS Data 2021/2022)

The scatter plot shows that as codesign moves towards the strongly agree, the constructability also moves towards the high end. Therefore, codesign positively impacts constructability.

Table 18 Pearson Correlation for H1

		Constructability
Codesign	Pearson Correlation	.633**
	Sig. (2-tailed)	.000
	N	100

Source: SPSS Data 2021/2022

Since the Pearson correlation is between -1 to +1 as suggested by Sekaran and Bougie (2016), we can say that Codesign directly affects the constructability. Further, the correlation is positive and is between 0.50-1.00, which means that the correlation is strongly positive. There is a 63.3% relationship between codesign and constructability. The significance or p value is less than 0.01, meaning that the chance of the relationship not occurring is less than 1%. (Pallant, 2020; Sekaran and Bougie, 2016)

Table 19 Regression analysis for H1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.633[a]	.401	.395	.38828
a. Predictors: (Constant), Codesign				

Source: SPSS Data 2021/2022

The R^2 value shows us that 40.1% of the of the data fits the model. (Sekaran and Bougie, 2016)

Table 20 Beta values and significance for H1

Model		*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*
		B	*Std. Error*	*Beta*		
1	*(Constant)*	*.627*	*.139*		*4.528*	*.000*
	Codesign	*.591*	*.073*	*.633*	*8.099*	*.000*
a. Dependent Variable: Constructability						

Source: SPSS Data 2021/2022

The Bivariate analysis of Codesign vs Constructability shows that it is statistically significant since the significance value is less than 0.05. Therefore, H1 is accepted since the correlation is reported to be 0.633 between codesign and constructability,

and its significance is also less than 0.05, with the regression model fitting by 40.1% (Pallant, 2020; Sekaran and Bougie, 2016)

H2: Codesign as a cocreation strategy has a significant impact on client knowledge among Sri Lankan Architectural and Engineering design start-up practices.

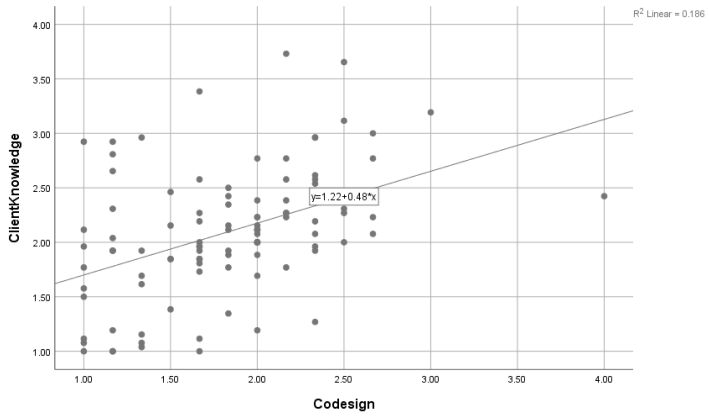
Since the Pearson correlation is between -1 to +1 as suggested by Sekaran and Bougie (2016), we can say that Codesign directly affects the client knowledge. Further, the correlation is positive and is between 0.30-0.49, which means that the correlation is moderately positive. The significance or p value is less than even 0.01, meaning that the relationship occurs 99% of the time. (Sekaran and Bougie, 2016)

The scatter plot on Figure 8 shows that as codesign moves towards strongly agree, the client knowledge also moves towards the high end. Therefore, codesign positively impacts client knowledge.

Figure 8 Scatter plot of Codesign vs Client Knowledge

Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral;

4 – Disagree & 5 – strongly disagree in SPSS analysis.



(Source: SPSS Data 2021/2022)

Table 21 Pearson correlation for Codesign vs Client Knowledge

		Client Knowledge
Codesign	Pearson Correlation	.432**
	Sig. (2-tailed)	.000
	N	100

Source: SPSS Data 2021/2022

Table 22 Regression analysis for H2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.432[a]	.186	.178	.53440

Source: SPSS Data 2021/2022

The R^2 value shows us that 18.6% of the of the data fits the model. Although the coefficient value is low, the significance is high (Sekaran and Bougie, 2016).

Table 23 Beta values for Codesign vs Client knowledge

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.224	.191		6.420	.000
	Codesign	.476	.100	.432	4.737	.000
a. Dependent Variable: ClientKnowledge						

Source: SPSS Data 2021/2022

The Bivariate analysis of codesign vs client knowledge shows that it is statistically significant since the significance value is less than 0.05. Therefore, H2 is accepted since the correlation is reported to be 0.432 between codesign and client knowledge,

and its significance is also less than 0.05, with the regression model fitting by 18.6% (Pallant, 2020; Sekaran and Bougie, 2016)

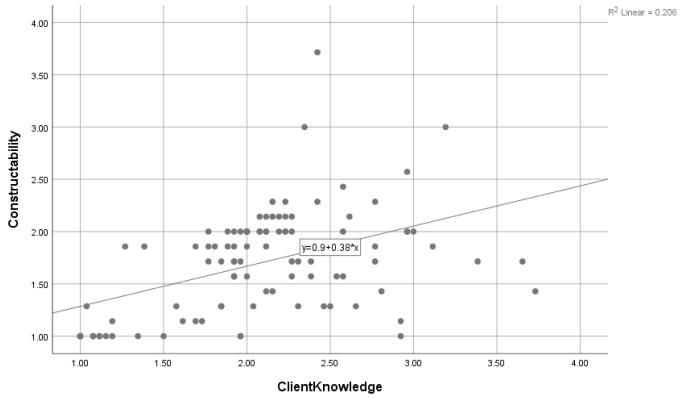
H3: Client knowledge has a significant impact on constructability among Sri Lankan Architectural and Engineering design start-up practices

Again the Pearson correlation is between -1 to +1 as suggested by Sekaran and Bougie (2016), we can say that client knowledge directly impacts the constructability. Further, the correlation is positive and is between 0.30-0.49, which means that the correlation is moderately positive. The significance or p value is less than even 0.01, meaning that the relationship occurs 99% of the time. (Sekaran and Bougie, 2016)

Figure 9 Scatter plot of Client Knowledge vs Constructability

Please note, Likert scale labelled as: **1 – STRONGLY AGREE; 2 – AGREE;** 3 – Neutral;

4 – Disagree & 5 – strongly disagree in SPSS analysis.



(Source: SPSS Data 2021/2022)

The scatter plot in

Figure *9 Scatter plot of Client Knowledge vs Constructability* shows that as client knowledge moves towards strongly agree, the constructability also moves towards the high end. Therefore, higher client knowledge positively impacts client constructability.

Table 24 Pearson correlation for Client Knowledge vs Constructability

		Constructability
Client Knowledge	Pearson Correlation	.453**
	Sig. (2-tailed)	.000
	N	100

Source: SPSS Data 2021/2022

Table 25 Regression analysis for H3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.453[a]	.206	.197	.44713
a. Predictors: (Constant), Client Knowledge				

Source: SPSS Data 2021/2022

The R^2 value shows us that 20.6% of the of the data fits the model. Although the coefficient value is low, the significance is high. (Sekaran and Bougie, 2016)

Table 26 Beta values for client knowledge vs constructability

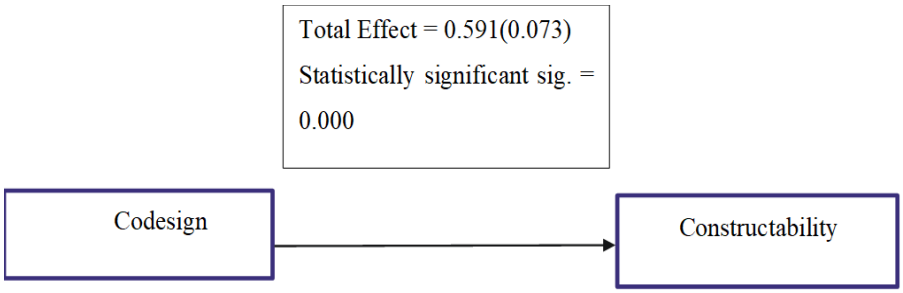
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.901	.166		5.444	.000
	ClientKnowledge	.384	.076	.453	5.036	.000
a. Dependent Variable: Constructability						

Source: SPSS Data 2021/2022

The Bivariate analysis of client knowledge vs constructability shows that it is statistically significant since the significance value is less than 0.05. Therefore, H3 is accepted since the correlation is reported to be 0.453 between client knowledge vs constructability, and its significance is also less than 0.05, with the regression model fitting by 20.6% (Pallant, 2020; Sekaran and Bougie, 2016)

H4: Client knowledge mediates the impact of codesign on constructability among Sri Lankan Architectural and Engineering design start-up practices

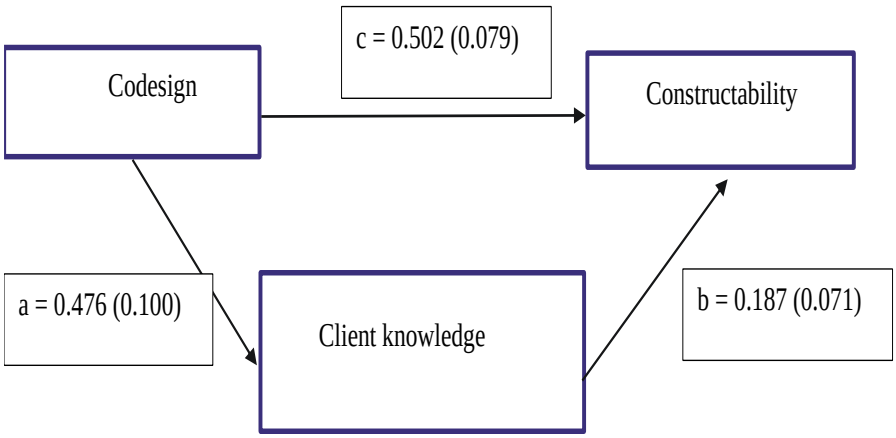
Figure 10 Total effect of codesign vs constructability



(Source: SPSS Data 2021/2022)

The total effect shows that there is a significant impact of codesign on the constructability of a project.

Figure 15 Mediation analysis



(Source: SPSS Data 2021/2022)

Table 27 Indirect effect and significance using normal distribution (Sobel Test)

	Value	s.e.	LL95CI	UL95CI	Z	Sig(two)
Effect	.0892	.0395	.0119	.1665	2.2610	.0238

Source: SPSS Data 2021/2022

Table 28 Bootstrap results for indirect effect

	Data	Mean	s.e.	LL99CI	LL95CI	UL95CI	UL99CI
Effect	.0892	.0930	.0512	-.0120	.0115	.2085	.2732

Source: SPSS Data 2021/2022

The z value being greater than 1.96 and the significance of the Sobel test being less than 0.05 shows that client knowledge has a considerable mediation role between codesign and constructability. Further, as the z value of 2.2610 falls outside the +/- 1.96 value, and the significance of 0.0238 is less than 0.05, client knowledge has a significant mediation role between codesign and constructability. (Abu-Bader and Jones, 2021; Yay, 2017) Therefore H4 is accepted.

5.13. Summary of Hypotheses Test Results

Table 29 Summary of hypotheses tests

Hypotheses	**Result**	**Empirical Evidence**
H1: Codesign as a cocreation strategy has a significant impact on constructability among Sri Lankan infrastructure design start-up practices	**Accepted** • Correlation – 0.633 • Significance – 0.000 • Regression model fitting by 40.1%	Mattelmäki and Visser (2011) as cited by Trischler et al., (2018); Prahalad and Ramaswamy, (2004)
H2: Codesign as a cocreation strategy has a significant impact on client knowledge among Sri Lankan infrastructure design start-up practices	**Accepted** • Correlation – 0.432 • Significance – 0.000 • Regression model fitting by 18.6%	Anumba, Egbu and Carrillo (2008); Combrinck and Porter (2021); Mattelmäki and Visser (2011); Nonaka et al. (1995); Prahalad and Ramaswamy (2004)

H3: Client knowledge has a significant impact on constructability among Sri Lankan infrastructure design start-up practices	**Accepted** • Correlation – 0.453 • Significance – 0.000 • Regression model fitting by 20.6%	Xiao, Ma and Li (2020)
H4: Client knowledge mediates the impact of codesign on constructability among Sri Lankan infrastructure design start-up practices	**Accepted** • z value – 2.2610	Brucks (1985) and Zhang et al., (2005) as cited by Xiao, Ma and Li (2020); Kelly, Donnelly and Skinner (1990); Plé (2016); and Xiao, Ma and Li (2020)

Source: SPSS Data 2021/2022

5.13.1. Cross Validation of Results

As an additional component, a total of 5 interviews were conducted among management consultants, although 6 interviews were planned, the difficulty to arrange for their time for an interview and the limited time for the research was considered and the cross validation was stopped at 5 interviews. Further, as the interviews were conducted, the same points seemed to be reiterated in different words and hence, it was concluded that the responses were adequate for cross validation. Thematic analysis was utilised to validate main factors and points researched in the study and any additional insights are discussed in chapter 5 as well.

5.13.2. Thematic Analysis for Cross Validation

Respondent 1, Mr. Lasantha Abeywickrama, Management Consultant, Trainer, and MBA Lecturer stated that “The idea has merit” on collaborative design. And that “Cocreation would be an effort where the client and the agency will be involved throughout the process”. He mentioned that having “a joint team of the client and the

agency who will work together in jointly developing and creating the campaign or whatever it is". Further, he also stated that the principle has applicability in the design industry of architecture and engineering since "ultimately you are doing something for the client" and that "Rework will come down" due to collaboration. "One cannot compromise on the technical requirements just because the client wants something done so, in which case I think it is very important that both parties come to a clear understanding as to who is the expert on what and the whole purpose of this joint development. That kind of understanding is necessary upfront I think." Moreover, he also mentioned that "there has to be a very good confidence building exercise", thus validating the factor of confidence under client knowledge. "The process will only work when the two parties are mature enough to understand each other's capabilities" and that "transparency among the two parties is critical", validating the transparency factor. He also stated that codesign "can lead to competitive advantage among start-ups in Sri Lanka. (Abeywickrama, 2022)

Respondent 2, Mr. Niroshan Madampitage, Management Consultant, Agile Coach and MBA lecturer, stated that he would "agree on our approach, how often do we meet, what are the meetings we are going to have together" with the client, which refers to time and frequency of engagement and "if you need further research you need to figure out whether you need a survey or whether you need to run interviews" which refers form of facilitation. He went on to describe that "setting the correct mindset" was important, like Abeywickrama's (2022) notion of attitude. Furthermore, he mentions that "you can apply agile and lean again, agile is to facilitate the process" and that "lean is to optimise on value added activities". He also stated that "proper foundation is a must, then engineering design is a must, then comes the architectural design" and "any approvals that you require from the government would define the constructability, meaning the operational performance and building performance framework factors which are again validated. He further stated that "you need to look at your budget and the costing around your construction" which refers to value engineering and mostly to cost/benefit analysis factors which are again validated. The client's "technical knowledge around the terms and the concepts

behind the construction. Then such clients can be closely involved in the design process" and that "they can challenge" and then "its ging to be a more constructive way of collaboration" and with the clients who "might not be well aware of the conceptual perspective" and would "rely on you" meaning the engineers and architects and so they would need to "present it in a simplistic way so that they understand it" and that "one thing very important is transparency". Hence this shows that the client's confidence, cognitive skill and experience are factors discussed. Further, the transparency factor is mentioned to be important, and "to put all these guys together" meaning the architects, engineers, clients etc which looks at the engagement as well as the form of facilitation and knowledge management and transfer. He also stated that "the perfect setup is start-ups for me" due to "less bureaucracy, less complexity in their approval process" and that "it gives you so much flexibility to build up a team that is ideal". Further, that "by making it a codesign, you actually manage a lot of risks". Hence the risk assessment factor is also validated. (Madampitage, 2022)

Respondent 3, Mr. Amitha Gamage, Start-up Consultant, stated that "you can do it while going on, as we build it, provided client's inputs are good or constructive or reasonable". Hence, the codesign principle is agreed on by both respondents. The importance of client's inputs shows that client knowledge plays a role in the codesign process. He also stated that "No Earth slip has occurred. In case if an Earth slip occurs, whether my building can withstand that, whether the safety of ours will be assured, so some of those kinds of things should be investigated." Therefore, the operational performance, building performance framework, quality management. He also stated that the "client's experience, knowledge, exposure will matter a lot". Hence, the client's experience factor to measure client knowledge is also validated. Further "since you are a start-up, there are no rules", "I think you are liberated", again as also mentioned by Abeywickrama (2022), Moreover he stated that codesign "is definitely a competitive advantage". (Gamage, 2022)

Respondent 4, Roshanga Wickremesinghe, Management Consultant and Trainer, stated that "sometimes when people don't know what they don't know, it is very difficult to work with somebody", which is the confidence factor of the client, as also mentioned by Abeywickrama (2022) and that a lot of "insights and inputs you can mine from the client's expertise", which means that the experience factor is also considered as stated by Gamage (2022) as well. Further, he stated that he would use "experiential learning" to "engage" them and "things like distractions are taken away". Thus, the engagement with the client, as well as the form of facilitation for the engagement are considered, and thus validated from the study. Further, he stated that in Sri Lankan projects, "they want to meet the fundamental function at the cheapest possible price", referring to cost/benefit analysis as well as value engineering, which are validated through the study. He mentioned that "exposure, travel, educational background, experience" would define the client's knowledge, which validates the cognitive skill factor as well as the experience factor. However, as opposed to Abeywickrama (2022) and Gamage (2022), Wickremesinghe (2022) states that in a start-up "they will be under tremendous pressure to get the output out at the cheapest cost" which again looks at cost/benefit analysis, but "it can also be the other way around, where their rules are very low, therefore they will be more design oriented" as mentioned by Abeywickrama (2022) and Gamage (2022) as well.

Respondent 5, Mr. Dhanushka Jayakody, Management Consultant, was more concerned about the level of engagement, on whether the end users are the clients or whether the client is a facilitator of the designed structures to other users, hence again validating the engagement factor as mentioned by Wickremesinghe (2022). Jayakody (2022) also stated that he "would make sure that there is a constant information loop" which refers to knowledge management and knowledge transfer factors, which are thus validated. Further it was mentioned that "regular meeting cadence to get the required output from the client" would be important, referring to the frequency of engagement with the client as well as the form of facilitation of these "meetings"., and that the number of engagements required "depends on the complexity" of the project. He also mentioned that it is "the responsibility of the relevant parties to make

sure that nothing adverse takes place because there is a codesign element to it" meaning that although there is an effect, the technical members of the project are responsible to ensuring constructability. Moreover, it was mentioned that it is the client's "technical ability" and "their knowledge of what the end users want". This refers to the client's cognitive skill, experience, and their confidence in what they want. Hence all three factors are validated again.

5.13.3. Summary of Cross Validation Results

Table 30 Summary of Thematic analysis results

Variable	Measures/Factors	Result	Empirical Evidence
Codesign	Form of facilitation	Validated Madampitage (2022) Wickremesinghe (2022) Jayakody (2022)	Combrinck and Porter (2021); Dietrich et al. (2017); Prahalad and Ramaswamy (2003)
	Time of engagement	Validated Madampitage (2022) Wickremesinghe (2022) Jayakody (2022)	
	Frequency of engagement	Validated Madampitage (2022) Wickremesinghe (2022) Jayakody (2022)	
	Transparency of information	Validated Madampitage (2022) Abeywickrama (2022)	
	Risk assessment	Validated Madampitage (2022)	
	Access to information	Not Validated	
Constructability	operational performance	Validated Madampitage (2022) Gamage (2022)	Bea (2005); Alshawi and Underwood, (1996); Green, (1990); Haider, (2009); Ireland, (2006; Low et al., 2008; Rezgui et al., 2010; Russell et al., 1994; Rwelamila and Savile, 1994; Tatum, 1990; Tatum, 1993 as cited by Kifokeris and Xenidis, 2017
	value engineering	Validated Madampitage (2022) Wickremesinghe (2022)	
	knowledge management	Validated Madampitage (2022) Jayakody (2022)	

	cost/benefit analysis	Validated Madampitage (2022) Wickremesinghe (2022)	
	quality management	Validated Gamage (2022)	
	building performance framework	Validated Madampitage (2022) Gamage (2022)	
Client knowledge	Experience	Validated Madampitage (2022) Gamage (2022) Wickremesinghe (2022) Jayakody (2022)	Brucks (1985); Zhang et al., (2005) as cited by Xiao, Ma and Li (2020); Kelly, Donnelly and Skinner (1990); Plé (2016); Xiao, Ma and Li (2020)
	Confidence	Validated Abeywickrama (2022) Madampitage (2022) Wickremesinghe (2022) Jayakody (2022)	
	Cognitive ability	Validated Madampitage (2022) Wickremesinghe (2022) Jayakody (2022)	

The factor of access to information was not validated through the thematic analysis. This could be argued saying that simply access to information will not give the client any understanding of the process and will not be able to interpret it on their own. (Prahalad and Ramaswamy, 2004)

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The key variables investigated in the study were codesign as the independent variable, constructability as the dependent variable and client knowledge as the mediator. The factor that gave the largest contribution to codesign was the form of facilitation with

a mean of 1.59, which was closest to the strongly agree point on the scale (number 1 was assigned to Strongly agree). The overall mean value of codesign was 1.82. Knowledge management gave the largest contribution towards constructability with a mean od 1.61. The overall mean of constructability was 1.70. The mediator, client knowledge had an overall mean of 2.10 with experience having the largest contribution with a mean of 2.08. Four hypotheses were tested. Hypothesis 1 was accepted since the correlation was 0.633, and its significance was 0.000, which is also less than 0.05, with the regression model fitting by 40.1%, showing that there was an impact on constructability from codesign. Hypothesis 2 was to test whether codesign and client knowledge were related, and it was proven, since correlation is reported to be 0.432 and its significance is 0.000 also less than 0.05, with the regression model fitting by 18.6%. Hypothesis 3 tested the relationship between client knowledge and constructability. It was also accepted in the correlation is reported to be 0.453 and its significance is 0.000 also less than 0.05, with the regression model fitting by 20.6%. Hypothesis 4 tested the mediating role of client knowledge between codesign and constructability. The z value of 2.2610 falls outside the +/- 1.96 value and the significance value of 0.0238 is less than 0,05. Hence, client knowledge has a significant mediation role between codesign and constructability. Further, all factors in the three variables were validated through the cross validation via thematic analysis, except for access to information. This could be because the client may not be able to interpret the information on their own. (Pallant, 2020; Hair *et al.*, 2019; Yay, 2017; Sekaran and Bougie, 2016; Urbano, 2013; Prahalad and Ramaswamy, 2004; Kline, 1994)

6.2. Managerial Implications

Codesign

Codesign was rated a mean value 1.82, indicating that it is significantly being evaluated by the respondents. 6 questions were asked about codesign, and the factors analysed were form of facilitation, time of engagement, frequency of engagement,

access to information, transparency of information and client's risk assessment, with form of facilitation having the highest mean of 1.59. Therefore, start-up design firm managers should focus on ensuring that the form of facilitation for since it is the most important factor to improve the codesign process. Hence, different forms of facilitation to ensure ease of access and modes that contribute to effective communication would be best suited.

Constructability

Constructability was rated a mean value 1.70, indicating that it is significantly being evaluated by the respondents. 7 questions were asked about constructability, and the factors analysed were operational performance, value engineering, knowledge management, cost/benefit analysis, quality management and the building performance framework, with knowledge management having the highest mean of 1.61. Therefore, start-up design firm managers should focus on ensuring that proper knowledge management techniques are set up for since it is the most important factor to improve the constructability process. Given that codesign has a significant impact on the constructability based on the findings of this research, managers could use codesign to improve collaboration among teams and thus improve knowledge transfer in the form of tacit-to-tacit knowledge transfer (socialisation). Hence, encouraging this knowledge sharing among teams could improve collaboration and the codesign process while helping improve the constructability.

Client Knowledge as a Mediator

This research proved that client knowledge has a significant mediation on the effect of codesign on constructability. Therefore, it is important for managers to focus on this and try to improve the client's knowledge by conducting workshops or small briefing in a manner that is simple so that the client finds it easier to navigate through the codesign process and their inputs become constructive. This ensures better constructability while the codesign process is being utilised.

6.3. Recommendations

Codesign

It is recommended that firms improve the form of facilitation for the codesign process before concerning on engagement, access and transparency of information and the client's risk assessment. Based on Table 10, frequency of engagement is the least important factor, in comparison to the other factors. However, with the advent of technology, online communication methods would probably be preferred for the form of facilitation. While they would reduce costs and be easy to access, ensuring that the message is delivered in real time is important, such as with video conferencing. The complete interaction of a physical environment would be much preferred and other precautions may have to be taken if the codesign is being done via online methods. Also, according to Madampitage (2022), collaboration is best when messages are directly relayed to reduce deviation, and interpretation of a message may change based on the mode of communication. Hence, real time communication methods are recommended for the codesign process. With the introduction of virtual reality, augmented reality and brain-computer interfaces, collaborative projects could be favoured with improved interaction even through digital communication. However, start-ups should consider the budgetary constraints they may come across.

Constructability

It is recommended that firms focus on knowledge management during the codesign process to improve constructability, while concentrating on operational performance, value engineering, cost/benefit analysis, quality management and the building performance framework as guides. Hence, according to Madampitage (2022), it is recommended that agile and lean methodologies are adopted during the process to pave a clear path. Further, proper knowledge management during the codesign process would help the client follow the conversations within the project team and prove more useful input. Further, collaboration within the team could improve

knowledge transfer and hence, codesign would help improve the issue of constructability that arises.

Client Knowledge as a Mediator

Since out of all factors, experience has the greatest impact on client knowledge. Hence, since firm are not able to control the client's experience, it is recommended that they rely on knowledge transfer and tactful communication. Further, according to Abeywickrama (2022), setting up a boundary on who is the expert in different areas and a proper conflict resolution mechanism upfront, would help the process go smoother and in fact could positively increase the effectiveness of the codesign process. Further, confidence building programs could improve the confidence of the client to communicate their needs, since confidence and cognitive skill had very slightly different mean values. The leadership is also important as verified by Madampitage (2022) since the technical part of the team would always clash with the client and one person may try to dominate the conversation, thereby subduing any constructive feedback from the client. The project manager plays an important role in the project by not only managing the project but also providing leadership. However, in a start-up, one of the few designers are probably the project manager. Hence, it is of utmost importance that a start-up designer improves on their leadership approaches. This contrasts with many start-up theories that believe the leadership factor comes into a business in the latter stages. Even in a design firm with one designer, they need to ensure that the client is given the opportunity to express their needs, figure out their future goals and preferences, while ensuring that the technicalities are effectively communicated, and a middle ground is achieved.

7. FUTURE RESEARCH DIRECTIONS

This research also has the potential to be viewed from an angle of design sprinting, which is quite rare in Sri Lankan architectural and engineering firms. The PDCA (Plan Do Check Act) model is quite often used in large organisations, but again has very low utilisation in start-up practices. Hence, future research could look at using

design sprinting and the PDCA model in the codesign process, as recommended by Madampitage (2022). Further, the use of collaborative approaches can be explored in other industries, such as management consultancy, software development and social entrepreneurship. Social entrepreneurship relies on identifying social issues and coming up with solutions, which again would benefit from a collaborative approach. Further, the expertise of the designers in the organisation could be considered as a variable in the study. It could be a mediator or even a moderator depending on the relationships. Leadership of designers could also be a variable to be explored as a new area. The data collection could also be focused on SMEs or larger organisations to observe the differences from a start-up environment. Thus, organisational culture and structure would then become significant variables to be studied.

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