DEVELOPING AN OFFSITE READINESS FRAMEWORK FOR INDIAN CONSTRUCTION ORGANISATIONS

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Abstract

The rapid growth of the construction industry and rising demand in housing and infrastructure facilities in India are challenges to the efficiency of Indian construction organisations. In view of the poor quality and under-supply of present day construction practices, the emergence of alternative and new technologies in construction have drawn the attention of many organisations. With this background, the Off-Site Construction (OSC) method has evolved as an efficient alternative approach addressing time, cost and quality concerns of the existing practices. Several construction organisations in India have recognised the need to implement OSC methods to achieve competitive advantage. In order to achieve successful implementation of OSC methods, the construction organisations must be fully aware of the operations and processes involved in working with OSC products, while the organisation itself must be prepared to customise according to the requirements of OSC methods.

The concept of Off-Site Construction has been drawing more attention from scholars. Various researchers have discussed about the existence of OSC practices in India. However, scholars have been less interested in exploring the status of OSC in India and factors affecting the uptake of OSC in the country. Therefore, the current research has aimed to develop the Off-Site Construction readiness framework to assess the preparedness of Indian construction organisations towards the application of OSC methods. The researcher has investigated the drivers and barriers for adoption of OSC techniques in India, and documented the results in this thesis. Current research has adopted the epistemological position of interpretivism and the ontological position of subjectivism as a research philosophy, issues that have been widely discussed in the chapter three “research design and methodology”.

The research identified that cost and time certainty, minimising on-site duration and achieving high quality are some of the driving factors towards the adoption of OSC techniques. On the other hand, longer lead times, client resistance and scepticism, along with lack of guidance and information are the potential barriers for extensive implementation of OSC methods in India. The seventeen constructs of the Off-Site Construction readiness framework are divided into four groups, entitled *Operational challenges, Broad execution strategy, Certainty in planning* and *Operational efficiency*. These groups were developed from the literature, self-administered questionnaires and semi-structured interviews in the different phases. The researcher also validated the refined framework through conducting case studies in three OSC-practicing construction organisations in India.

The proposed Off-Site Construction readiness framework will guide the practitioners in assessing the OSC readiness of the construction organisations in India. The assessment

will enable the organisation to evaluate and to benchmark its process in strategic and operational phases. The framework will also identify the areas of concern and the scope for further development or change in order to get optimal advantage of OSC methods. Hence, the research recommends application of the proposed framework in the OSC-practicing construction organisations in India in order to evaluate their current OSC readiness and to achieve competitive advantage. Though this assessment framework was proposed for India, it has a potential to serve as a general guide for OSC practitioners, policy makers and other key stakeholders involved in improving quality of the construction industry globally. In the real world implementation, the contribution of this research will improve awareness, increase confidence and strength of organisations in the execution of OSC techniques in Architectural, Engineering and Construction domains.

Declaration

This thesis is presented as an original contribution based on Doctorate of Philosophy research at University of Salford, Salford, United Kingdom and has not been previously submitted to meet requirements for an award at any higher education institution under my name or that of any other individuals. To the best of my knowledge and belief, the thesis contains no materials previously published or written by another person except where due reference is made.

 (Signature)

Deepthi Bendi

…13.06.2017 (Date)

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List of Abbreviation

CIDB	Construction Industry Development Board
CMM	Capability Maturity Model
COA	Council Of Architecture
CSF	Critical Success Factors
GOI	Government of India
HPL	Hindustan Prefab Limited
IBS	Industrialised Building System
ICT	Information and Communication Technology
IEI	Institute of Engineers India
IIA	Indian Institute of Architects
IMMPREST	Interactive Method for Measuring PREassembly and STandrdisation
MMC	Modern Methods of Construction
OSC	Off-Site Construction
OSF	Off-Site fabrication
OSM	Off-Site Manufacturing
OSP	Off-Site Production
PMMM	Programme Management Maturity Model
PMO	Process Model of Organisation
RACE	Readiness Assessment for Construction Engineering
S&P	Standardisation & Pre-assembly
SPICE	Standardised Process Improvement for Construction Enterprises

Chapter 1 | Introduction

This chapter introduces the thesis and presents the overview of the research that has been undertaken. It provides a background to the research topic, which is offsite construction and Indian construction industry. It discusses about the current challenges and opportunities of the construction industry in India. It also details the research problem, aim, objectives and the need for research. The chapter provides the evidence to support the need to develop the OSC readiness framework for construction organisations in India. It also presents an outline of the research and the structure of the thesis.

1. 1. Background to the research

In general, the construction industry significantly contributes to national social-economies (Oladinrin et al., 2012). The activities of construction industry are important to achieve the national development goals such as providing shelter, infrastructure and employment (Stasiak-Betlejewska and Potkány, 2015). In India it is considered as one of the major economic sectors, standing as the second largest industry (Auti and Skitmore, 2008 and Laskar and Murty, 2004). India is one of the growing countries in Asia. It occupies the major portion of South Asian subcontinent. It is spread of over 3.3 million sq. km. In terms of terrain, the mainland comprises of four regions (India gov, 2017). India is the second most populated country with 1.31 billion people (UN report,2015). There are five different climate zones in India (Energy Conversation Building Code, 2016). The construction industry is largely driven by Government of India investments on core infrastructure projects and creation of urban infrastructure (Maniar, 2011). India is expected to accommodate six mega cities with population of above ten millions by 2030 (NITI Ayog, 2017). Gupta et al., (2009) envisages that construction industry in India has the ability to grow further with the ongoing economic development, industrialisation, and urbanisation. In recent years, the Indian economy has grown at a rapid pace and the construction industry is playing major role in accelerating this growth. Current huge investments in infrastructure development are resulting in massive construction activities in India. Table 1.1, below illustrates the

growth of investment in the construction industry. According to Arif et al, (2009), the investment in total construction is around $70 billion per year. Research by Syal et al. (2006) discussed the possible investment of around $163 billion in the next 10 years for infrastructure development. On the other hand, the working group on construction appointed by the Planning Commission of India (2007-12) envisaged this investment to reach $280 billion in a span of just five years. The magnificent growth in infrastructure investment is prominent in the existing literature, though there is difference in the estimated investment by various researchers . This also portrays the humongous expansion in industry, infrastructure, housing and other projects in India.

Table 1.1. Estimated investment in Indian construction industry in billions, USD.

Year	**Residential Construction**	**Non-Residential Construction**	**Civil Engineering Construction**	**Total**
2008	8.0	5.19	115.24	**128.43**
2009	8.62	5.33	122.38	**136.33**
2010	9.24	5.45	129.52	**144.21**
2011	9.86	5.58	136.55	**151.99**

Source: Shrivastava and Chini (2009)

The Government of India allowed 100 percent Foreign Direct Investment in the real estate and infrastructure sectors (Nihas et al., 2017). This will catalyse construction activities across the country in the coming days. The growth in the construction industry during 2014-15 is estimated as 4.5% (NITI Ayog report 2014-15). According to Accenture and CIDC (2012), India will continue to be among the fastest growing countries in terms of construction output in the next ten years. The construction market is expected to grow at 4.7 percent globally during 2015-2020. During the same period, India is expected to grow at 7.6 percent (Accenture and CIDC, 2012). This shows the magnitude of construction activities in India when compared with other countries.

Parallel to the development, the Indian construction industry is gradually becoming sustainable. The past decade has witnessed significant growth in the green foot print in India (Arif et. al., 2012). Sustainability was prioritised among the top issues in the sustainable development agenda 2030 as well as the research and innovation of the

construction industry (Government of India, 2017; Arif et. al., 2012; and Arif et. al., 2009). However, the increasing need in the housing and infrastructure in India is challenging any sustainable performance here (Shrivastava and Chini, 2009). Along with this, there are several factors that have impacted on the construction industry in the past decade (Arif and Egbu, 2010). The industry in India is expected to facilitate the growing population and increasing need for infrastructure (Arif et. al., 2012b). On the other hand, it is facing major challenges in achieving quality and speed in construction. Poor quality, delays in completion, high demand and lack of construction project management skills are challenging growth and consistency in the industry (Arif et al., 2012a). The working group report (2007-12) alerted the industry on the current time and cost over runs. The same report also recommended the adoption of alternative technologies to improve the total productivity and repair the current image of the construction industry. Along with this, new challenges due to the risks involved in design and production associated with structural reforms push towards a major shift in current practices (Liu et al., 2007 and Young et al., 2008). In this situation, the whole industry is under extreme pressure to reduce time and cost of construction and has become committed to creating a sustainable built environment.

In the global context, several researchers have documented similar trends of growth in construction activities with poor productivity in other countries. Reports like “Rethinking Construction” by Egan (1998) and “Constructing the Team” by Latham (1994) analysed the barriers to efficiency in the construction industry in the UK. These reports also recommended major reforms in current construction methods and practices. Similarly, in the U.S., a report by the Committee on Advancing the Competitiveness and Productivity of the U.S. Construction industry (Haas, 2009) acted as a catalyst for quality enhancement in construction projects. This illustrated the global concern about improving the existing practices in the industry.

In this background, offsite construction technology has evolved as one of the potential alternatives to the traditional construction methods. In practice, off-site construction itself developed as an individual concept, though it has connections to lean construction,

just in time and other modern theories in construction. According to Pan & Arif (2011a), off-site construction significantly addressed the environmental dimension of sustainability through reduction of waste (Jaillon and Poon, 2009); the economic dimension of sustainability through mass customisation and the social dimension of sustainability by providing better and safer working conditions (Burgen and Sansom, 2006, cited by Pan & Arif, 2011). Many research findings demonstrated that offsite construction techniques offer numerous advantages such as minimising construction schedules, reducing delays, reducing the number of skilled labour onsite, increasing project quality and improving onsite safety performance (Blismas et al., 2005; Goodier & Gibb, 2005). Various studies from the developed and developing nations reported many similar benefits in utilising OSC techniques in terms of improving quality, scheduling , safety, improved labour productivity and more efficient equipment utilisation (Blismas and Wakefield, 2009; Goodier and Gibb, 2007; Goulding et al., 2012; Lu, 2009).

The trend of offsite construction has gained momentum all over the globe (Arif et al., 2012; and Goodier and Gibb, 2007). Offsite technologies were well received by a majority of the practicing nations across the developed and developing world. Significant interest was observed in OSC trends and practices globally in research publications, as well as in industrial implementation (Blismas et al., 2006; Goulding and Arif, 2013). According to the Construction Industry Council (CIC), the UK could achieve greater benefits from using modular buildings instead of traditional construction practices (CIC, 2013). Similar results were documented in other nations, including Australia, USA, Europe, HongKong, China, Singapore, and Malaysia (Azhar et al., 2013; Badir et al., 2002; Gibb, 2001; Goulding & Arif, 2013; Pan & Gibb, 2004; Pasquire & Gibb, 2002). The majority of these studies also documented similar advantages in using OSC. Such overwhelming benefits made off-site construction (OSC) a viable potential alternative to existing traditional construction practices.

1.2. Off-Site Construction in India

The concept of Off-Site Construction first started in India with the foundation of Hindustan Housing Factory, now known as Hindustan Prefab limited (HPL) (Smith and

Narayanamurthy, 2008). It was established by Jawaharlal Nehru, the first prime minister of India. It manufactures precast concrete elements for architectural and civil projects throughout the country (Smith and Narayanamurthy, 2008 and Hindprefab, 2017). Some researchers discussed about Off-Site Construction in India under the name prefabrication (Smith and Narayanamurthy, 2008 and Villaitramani and Hirani, 2014).

Villaitramani and Hirani, 2014 observed that OSC materials are popular for the durability and quality in India. However, there are arguments that OSC products are yet to receive appreciation in India (Arif et al., 2012a, Smith and Narayanamurthy, 2008 and Swahney et al., 2014). Villaitramani and Hirani (2014) have suggested the use of OSC methods for optimum use of scarce resources and to address the mass housing crisis in India.

Along with the government led organisation (HPL), there are some private organisations working on the OSC projects in India. L&T, Kirby international, Minaean Habitat India, Octamec group and Prefab infra are some of the providers of OSC in India. L&T owns heavy engineering workshops in five states with total fabrication capacity of over 150,000MT per year (Larsentoubro, 2017 and Villaitramani and Hirani, 2014). The Minaean Habitat India is a subsidiary of Minaean International Corporation, Canada (Minaeanindia, 2017). This organisation runs a modular building division, where structures are designed, engineered and prefabricated ready for use within four days of receipt at site (Smith and Narayanamurthy, 2008). This organisation is engaged in the development, manufacturing and construction of cost-effective low to mid-rise residential and commercial buildings in India (minaeanindia, 2017). Kirby Building Systems India Ltd. is an affiliate of Alghanim Industries, Kuwait. It has manufacturing facilities in two states with annual capacity of 200,000 MT (Kirbyinternational, 2017, Smith and Narayanamurthy, 2008). Kirby India manufactures Pre-Engineered Steel Building (PEB) solutions. This orgainsation has manufactured and delivered 65,000 buildings in 70 countries (Kirbyinternational, 2017). Existence of such organisations proves that OSC methods have been gaining popularity in India. Majority of these industry players are manufacturing trademark solutions. Smith and Narayanamurthy,

(2008) also claimed the continuous growth of OSC methods in India due to the increasing demand of fast and affordable housing.

1.3. Research Problem statement

The construction industry has often been criticised for its slow adoption of emerging technologies (Yang et al., 2007). The construction industry apparently lagged behind other industries in taking advantages of new technologies and innovative practices (Nadim & Goulding, 2011). However, this trend has been changing in recent years. As mentioned above, globally there is growing awareness of the use of OSC techniques. Though OSC has received wider acceptance in other practicing nations, it has yet to gain momentum in India, and the country has only began considering using these practices in the recent years (Arif et.al., 2012a). While innovation in the construction industry has often been observed as slow moving in the case of India, the technological 'conservatism' (Tiwari, 2001) is further hindering the shift towards new methods and innovative practices. However, Yaghoubi (2013) asserted this difference between the levels of acceptance in various nations. According to his research, the degree of implementation and level of investment varies across the world from country to country, due to the different work cultures, government policies, incentives the nature of organisations.

There are inefficiencies in the construction sector in India (Arif et al., 2012a; Sawhney et al., 2017 and Nihas et al., 2017). In the literature, several researchers reported about time and cost overruns (Singh 2010; Satyanarayana and Iyer, 1996; Swahney et al., 2014; Kumar 2016). Nihas et al., (2017) stressed that time and cost overruns exist in almost every construction project in India. According to the Planning commission report (2011) lack of standards and low use of technology across the construction supply is challenging the performance of construction sector in India. Gupta et al., (2009) pointed the poor quality of planning and engineering design, problems in land acquisition, weak performance management, and scarcity of skilled and semi skilled workers in the discussion about challenges of construction sector in India. According to Nihas et al., (2017), the construction industry comprises of 31 million people. Amongst this, only 10 percent is the skilled workforce. The research conducted by Sawhney et

al., (2014) identified the state of poor or no incentives for OSC practices and the use of other modern technologies as one among the top fifteen challenges being faced by Indian construction sector. The other challenges in line in the context of current research include standardisation of contracts, contractual procedures, procurement systems and project delivery methods; streamline and standardise project approvals and statutory sanctions.

The time delay in Indian construction projects had been discussed by various researchers. In a comparison study of international development projects in India, China, Bangladesh and Thailand, Ahsan and Gunawan (2010) found that construction projects in India stood with worst schedule performance. Nihas et al., (2017) forecasted a serious threat in future for the construction industry due to the present inefficacy of the industry. Gupta et al., (2009) warned about the inefficiencies and potential loss of $200 billion in the GDP of the financial year 2017. Housing shortage is another major challenge for the construction industry in India. According to the National Building Organisatoins' housing data – 2012, India needs 18.58 million houses. The eleventh five year plan had focused on the housing shortage, expanding infrastructure and need for sustainable development in India. Studies conducted by Arif et al., (2009), and Jha and Devayya, (2008) found that India is lacking international experience in construction projects, primarily in large scale projects and development of physical infrastructure.

Sawhney et al., (2014) recommended a long-term strategic approach to address the socio-economic needs of the country. Further, the same research also stressed the need for a critical study of the construction sector in India. The government of India is aiming to make inclusive, safe, resilient and sustainable cities and human settlements (NITI Ayog report 2014-15). The eleventh five year plan made recommendations to use modern technology methods in construction sector to enhance energy and cost efficiency, productivity and quality. Smith and Narayanamurthy, (2008), Arif et al., (2012a), Villaitramani and Hirani, (2014) recommended successful implementation of Off-Site Construction practices to reduce cost and improve the quality of housing in slums in India.

The government and researchers are suggesting improvements in the current unsustainable pattern of project delivery (Adetunji et. al., 2003 and Arif et. al., 2009). Carter et al., (2008) also highlighted the greater public demand for sustainable products and services in the contemporary construction industry. The Construction Working Commission Report- India (2007-12) made stringent recommendations on improving quality and standardisation, as well as technology upgrading and cost reduction in various construction projects. According to this report, there is an immediate need for "*A national strategy and policy frame work focused particularly on productivity enhancement and cost reduction to match with work load and delivery targets while satisfying the sustainable development and growth of (the) construction industry*" - Working Group on Construction, Report: 2007-12, P:VI).

There are traces of similar recommendations from various policy makers and research groups. This was discussed in detail in the section titled 'Global Trends' in the literature review. However, to mention a few, research conducted in developed nations like U.K., U.S., and Australia, as well as developing nations like China, Malaysia and Hong Kong, have exemplary policies and strategies for enhancing construction productivity (Haas, 2009; Arif & Egbu, 2010; Scoping Report- New Zealand, 2007; Jaillon and Poon, 2008). OSC attained a huge focus in major recommendations to achieve greater productivity and pace in construction projects. Many researchers have foreseen offsite construction as the future of the construction industry. Industry advisors and experts have repeatedly recommended that the industry use more offsite and standardisation in order to increase quality and reduce cost and time (Pan et al., 2007; Arif and Egbu, 2010; Tam et al., 2007; Goodier and Gibb, 2007; Badir et. al., 2002 and Blismas et. al., 2009).

Goulding et. al., (2012a) examined the challenges and drivers for offsite uptake globally based on the literature and questionnaire surveys. They also highlighted the need for further investigations on the attributes affecting people, process and technology in the OSC context. Recent studies in India reported a lack of international exposure to construction activities, especially in large scale projects and physical infrastructure

development (Arif et. al., 2009; Jha and Devayya, 2008). Other remarks include the dominance of traditional practices which are highly labour intense and uncertainty in cost and time schedules (Tiwari, 2001 and Auti & Skitmore, 2008). Therefore, addressing the high demand for housing and infrastructure facilities, sustainable built environment, global knowledge transfer and exchange into Indian construction industry are the need of the hour.

The review of literature highlighted the importance and advantages of using OSC techniques, but as discussed above, the current level of OSC uptake is low in India. However, it is gradually spreading into the industry there. Some work was initiated regarding the Indian scenario in recent years (Arif et al., 2012; Smith and Narayanamurthy, 2008), but there is no comprehensive study on the status of OSC in India. Also, there is no evidence of successful implementation of OSC in the Indian context in the literature. In the highly competitive construction industry, the best organisations constantly search for proven technologies for a competitive advantage (Yang et al., 2007), but lack of information regarding the benefits from new technologies and lack of awareness discourages industry stake holders from taking up new practices (Yang et al., 2007). Hence, there is need for tangible evidence of advantages from using different levels of OSC techniques. Organisations quickly identified the potential benefits of efficient off site practices in many countries (Azman et al., 2012; Haas and Fangerlund, 2002). Researchers from other practicing nations such as the UK, USA, Australia, China and Malaysia have documented the experiences and lessons regarding OSC in the literature, but in the developing nations there is still a strong need for tangible research (Goulding et. al., 2012a; Nadim & Goulding, 2010). Many researchers have extensively studied OSC in various developed nations, and some of them demonstrated the role of strategy in implementing it. Gibb (2001) revealed that a project strategy is essential to changing the project process from ‘traditional construction’ to ‘manufacturing and installation’. Similarly, Egbu (2004) believed that organisational strategies for innovation are “path-dependent”. According to Egbu (2004) innovation strategies of organisations are strongly constrained by their current position and core competencies, as well as the specific opportunities open to them in

future. Aldridge et al., (2001) clarified that lack of formal measurement procedures or strategies in the context of offsite is hindering the extensive usage of OSC.

While some studies demonstrated the importance of strategies, Goulding et al., (2012b) highlighted the lack of feasible business process models for promoting OSC in a meaningful way. Blismas et.al., (2006) revealed that the evaluation of the degree of industrialisation of a component or building system production in offsite construction is inadequate in the construction industry. Blismas et. al., (2006) also highlighted the need for the holistic and methodical assessments of the applicability and overall benefit of these solutions. Further, Smith & Narayanamurthy (2008) stressed the need to investigate an appropriate prefabricated building system to fulfill the housing shortage in the present context. Kamar et. al., (2009) highlighted the need for kick-starting projects in order to create more opportunities and spilling out the effect to the entire industry. It is time for rethinking about how construction projects could be conceived, planned and executed in order to achieve maximum benefits through OSC practices.

On the other hand, the current scenario of high demand for housing and shortage of skilled labour could be perceived as an opportunity for an offsite spread in India. According to Goodier and Gibb (2007) the commonly-cited lack of skilled workers in the construction industry is an ideal opportunity for the increased use of OSC. However, organisations currently lack adequate resources to facilitate and satisfy market needs if extensive offsite practices are implemented in the industry (Goodier and Gibb, 2007). According to Pan and Arif (2011), shifting efforts from offsite to onsite might not guarantee efficient results in all cases. The construction organisations have to be mindful of several factors before selecting OSC. Regarding OSC, several researchers such as Gann (1996), Gibb (2001) and Pan and Arif (2011) articulated the prominence of various attributes at both strategic and operational levels. In many countries, the decision to use OSC methods is still based on ‘anecdotal evidence rather than rigorous data’ (Pasquire and Gibb, 2002).

As discussed above, currently there is very less research available on offsite construction in India. In addition, there is no comprehensive industry-wide study on the

impacts of OSC usage in the construction industry. In recent years, many Indian construction organisations are responding to the increasing interest in OSC and manufacturing construction, but lack of awareness and some confusion has discouraged any intensive implementation of it. The organisations are also sceptical about their capabilities of integrating OSC practices in their construction activities (Arif et al., 2012a)

Therefore, the current research is intended to fill this gap in literature. The researcher is aiming to develop an off-site construction readiness framework for the Indian construction organisations. According to Keupp and Gassmann, (2013) it is essential to compare and test the existing knowledge/practices in an organisation before introducing any new innovation. Therefore, the researcher is investigating the current state of OSC practices in India and documenting the existing knowledge. The derived OSC readiness framework would assess the maturity level of the construction organisation in India. The mechanism of an 'offsite construction readiness framework' will have some similarities with the Capability Maturity Models (CMMs). According to Page et al., (2004) CMMs provide guidance to organisations on defining processes. They describe what activities must be performed in order to meet certain criteria. By exercising through the offsite readiness framework, the organisations would not only gain knowledge on OSC, but also know their capability for adopting OSC in construction projects. The model dictates the capability of the organisation in order to implement OSC in certain construction activities. Thus, the maturity level of the organisation, along with the characteristics, can be studied based on the results obtained from the OSC readiness model. In addition to the OSC readiness framework, the research proposes a strategy for extensive implementation of off-site practices in India.

1.4. Research questions

Current research is aiming to answer the following research questions.

1. Are Indian construction organisations aware of off-site construction approach and its benefits? What is the current status of off-site construction in India?

2. What factors drive and hinder construction organisations in pursuing offsite-construction practices in India?

3. What is an OSC readiness framework? What are the essential constructs of it? What are the advantages of the OSC readiness framework?

4. How ready are Construction organisations to adopt OSC techniques in India? How can we evaluate an organisations' readiness to adopt OSC?

1.5. Research Aim and Objectives

1.5.1. Aim

This research aims to develop an off-site construction readiness framework for Indian construction organisations.

1.5.2. Objectives

The above research aim can be achieved through the following objectives.

1. To understand and document the offsite construction paradigm and influencing factors through literature review;

2. To investigate the drivers and barriers towards the adoption of off-site construction in India and document existing practices in other countries;

3. To conceptualise a readiness framework to assess the maturity level and preparedness of construction organisations for adopting Offsite Construction (OSC) practices in India;

4. To test and validate proposed framework in construction organisations in India;

5. To demonstrate findings, reach a conclusion and suggest recommendations.

1.6. Research outline

The design of this research engaged both quantitative and qualitative approaches. The researcher started with the review of literature to understand the existing research on the construction industry in India, and Off-Site Construction. This helped in gaining knowledge of the current issues in the construction industry in India, and identifying the

research problems. Further, the researcher developed the research questions, aim and objectives. Based on the aim and objectives, a detailed literature review was conducted to understand the concept of OSC, global practices, and the readiness assessment tools. The literature review helped the researcher in identifying influencing factors for the successful adoption of OSC, and gaining knowledge on the existing readiness assessment tools. This further directed the researcher to adopt both quantitative and qualitative approaches to data collection and analysis. Different data collection tools (questionnaires, and interviews) were used in order to develop the OSC readiness framework for construction organisations in India. The developed framework was validated through three case studies. A detailed discussion on the research methodology is provided in chapter three. The section below outlines the research methods used to achieve each of the research objectives.

Objective One: The researcher conducted literature review to achieve the first objective. The literature review provided deep understanding on the concept of OSC, and documentary evidence of the key factors related to the application of OSC in the construction industry in general. The researcher has drawn knowledge about the definition of OSC, various terminologies, characteristics, benefits, and key issues involved in implementing OSC in construction projects.

Objective Two: A combination of literature review and questionnaire survey was conducted to achieve the second objective of the research. The researcher searched the existing literature to identify potential drivers and barriers for OSC implementation in various countries. This search revealed the existing factors and current practices of OSC across the globe. The researcher then designed a questionnaire tool based on the data obtained from the literature. This questionnaire was sent to practitioners in Architecture, Engineering and Construction domain in India. This survey was conducted to obtain a full range opinions, and practical observations of the stakeholders including, architects, project managers, engineers, contractors and consultants in the construction industry in India. The results of the questionnaire survey revealed the existence of OSC, key factors, drivers and barriers towards the implementation of OSC in India. Thus the

results from both literature review and questionnaire survey assisted in achieving objective two.

Objective Three: In order to achieve the third objective, the researcher conducted both literature review and semi-structured interviews. The literature review provided the current state – of – art – of readiness assessments used in construction industry. This helped in understanding the maturity levels and evaluation process of readiness assessment tools. The researcher then developed the conceptual OSC readiness framework based on the extracted variables from the questionnaire survey. The conceptual readiness framework comprised of 17 variables in 4 proposed groups, and three defined readiness levels. The researcher then examined the conceptual framework through semi structured interviews. The researcher interviewed five professionals in the construction industry, each with more than fifteen years of experience in the construction industry and more than five years of experience in working in OSC projects. The semi structured interview aimed to investigate the classification and nomenclature of groups, scope and definition of the sub-factors, definition of the three maturity levels, adequacy of the number of levels and their appropriateness for assessing the OSC readiness and applicability of the suggested OSC readiness framework. The results from the semi-structured interview have helped in refining the framework and thus the researcher achieved the third objective of this research.

Objective Four: The researcher tested the refined OSC readiness framework through three case studies. The researcher developed a case study guide to document observation based evidence and interview based evidence. The interview guide helped in assessing the OSC readiness level of the organisation against operational challenges, broad execution strategy, certainty in planning, and operational efficiency. The results of the case studies revealed that the proposed OSC readiness framework was able to evaluate the OSC readiness of construction organisations in real scenario.

Objective Five: In order to achieve this objective, the researcher documented the findings of the literature review, analysis of data obtained from questionnaire survey, semi structured interviews and case studies. The research made some recommendations based on the findings.

1.7. Research scope & limitations

This research study is broadly focused on developing an off-site construction readiness framework for Indian construction organisations. In the process, the research investigates the current state of OSC in India along with the drivers and barriers for adoption of its practices. The research scope and the population for data collection is limited to construction organisations in India. All required data was collected through a questionnaire survey, interviews and case studies. India is a vast country with divergent geographical, climatic and cultural phenomenon. Random sampling was used to ensure that results indicate the responses of the industry on the whole. The case studies of the proposed OSC readiness framework will be evaluated within a limited number of organisations in the Indian construction industry.

1.8. Contribution to knowledge

The key contribution of this research is the off-site construction readiness framework for Indian construction organisations. Furthermore, the research provides knowledge on the drivers and barriers against implementation of offsite techniques in the Indian construction industry. No similar studies have been conducted on OSC in this context. This research anticipates filling the gaps in existing literature, particularly within this area. The researcher also attempts to learn lessons from the OSC practicing nations and customise everything for the Indian context.

1.9. Structure of the thesis

Current thesis comprises seven chapters. The structure is presented in the figure 1.1 below. *Chapter 1* introduces the view of this research. It presents the research background, problem statement, research questions, aim and objectives, the scope and limitations of current research and contribution to knowledge.

Chapter 2 reviews the literature on Off-Site Construction. The review explains the history, benefits and the usage of OSC in the construction industry. This chapter presents the global trends in the practice of OSC techniques and various influencing factors in implementing OSC techniques. Next, it documents the critical success factors, drivers and barriers in the adoption of OSC techniques. This helps in structuring factors

to investigate in the case of Indian construction organisations. The next sections focus on the readiness assessment tools in the construction industry. The researcher presents detail review of selected readiness assessment tools and maturity models in this chapter.

Chapter 3 presents and justifies the research design and methodology adopted for current study. This explains the philosophical research assumptions underpinning current study and research strategy. The chapter explains the data collection, the philosophical stance (the ontology and epistemology) and the ethical considerations of this research work.

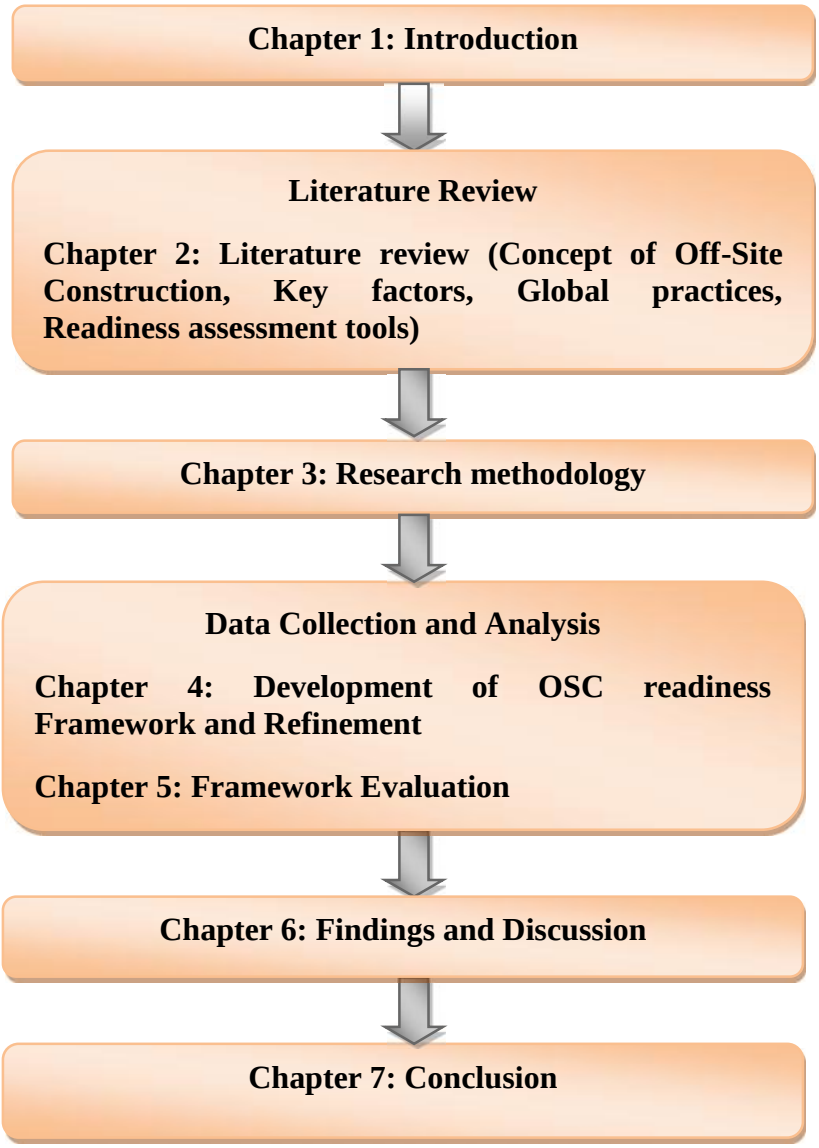
Chapter 4 describes the development of OSC readiness assessment framework. It also presents the drivers and barriers for the adoption of OSC in India. The chapter contains the descriptive analysis of the data obtained from questionnaires, discussion of factors influencing the successful implementation of OSC methods in India, exploration of OSC readiness factors, development of OSC readiness framework and refinement through interviews. The chapter presents the refined OSC readiness framework for further validation.

Chapter 5 contains the validation process of the refined OSC readiness framework. The chapter presents the findings of three case studies of Indian construction organisations. Each case demonstrates the back ground of the organisation, and assessment results in operational challenges, broad execution strategy, certainty in planning and operational efficiency factors.

Chapter 6 discusses the findings from the three case studies and evaluates the status of OSC practices in the three Indian construction organisations. It also presents the validity of the refined OSC readiness framework in the practical scenario.

Chapter 7 presents the overall conclusions of the research. It also discusses the answers for the research questions, contribution to knowledge from this research. It concludes with suggestions for future research.

Figure 1.1: Structure of this thesis



Chapter 2 | Literature Review

This chapter presents an understanding of Off-Site Construction (OSC) and the different terms from the existing literature. The first part documents the relevant literature on OSC, the terminology, the various practices, global trends and development strategies. The chapter portrays the larger picture of the application of OSC techniques across the globe, and also attempts to identify the similarities that can be drawn with respect to the current research area, India. In detail, it provides a discussion of the major types of OSC techniques, the various methods involved, the benefits, the influencing factors, the drivers and barriers towards OSC adoption and the critical success factors of OSC.

The second part covers the literature review in regards to the definition of readiness model, and the various readiness models in the construction industry, their processes and methods. Thus, the chapter reviews the current state of OSC in various countries across the globe and the readiness tools available in the literature. The outline of this literature review is shown in the figure 2.1 below.

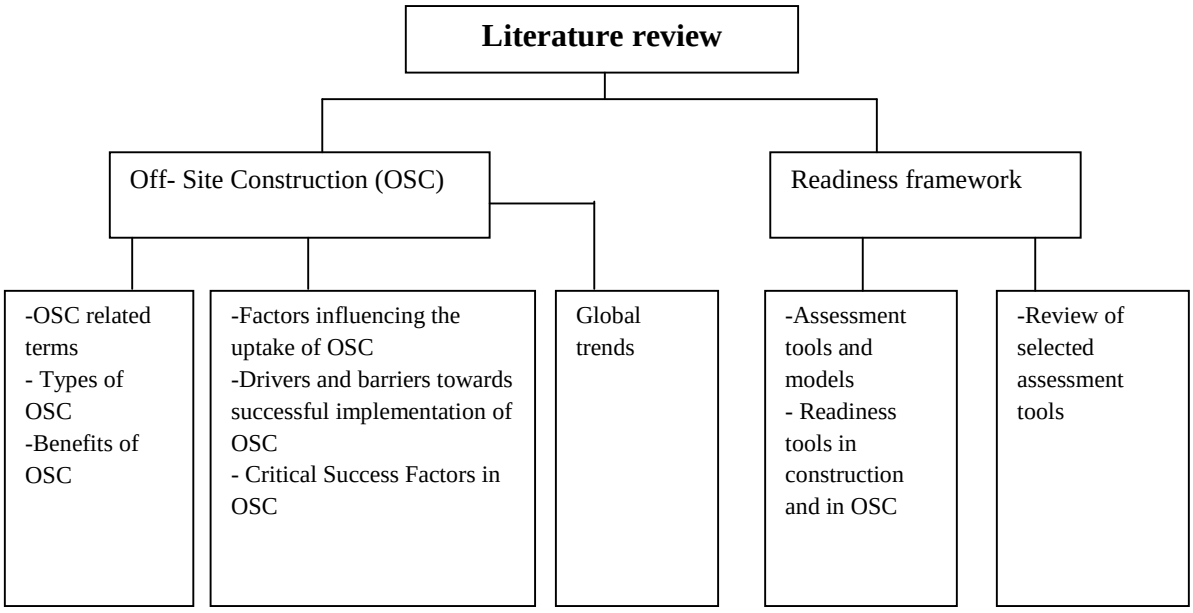


Figure 2.1 Outline of the literature review

2.1. Background

Off-Site Construction has emerged as a new paradigm to attend the growing needs of the construction industry. There is significant amount of literature available on the Off-Site Construction methods. Several researchers have discussed about the diversification of the concept, the terminology and definition of OSC in multiple contexts and backgrounds. Gibb (2001) has documented the existence and prominence of OSC in history.

In ancient times there were also traces of adoption of offsite techniques. For instance, as mentioned by Arif (2009), smaller bricks were replaced by big boulders in the construction of pyramids in ancient times. This is similar to the modern day's practices of using pre-fabricated panels. Gibb (2001) has documented the existence and prominence of OSC in history, recording the traces of manufactured construction in history. His research has also identified that OSC was extensively used post-World War II due to the acute shortage of housing. Statements from famous architects were documented in the literature. Walter Gropius stated that "the idea of industrialisation can be translated into reality by repeating individual parts. This makes mass-production possible and promotes low cost (Davies, 2005). Gropius and Le Corbusier have stated that, "OSC is to achieve better architecture for a better world". Davies (2005) explored the history of houses, houses-on-wheels, and link between the offsite factory production and prefabricated housing in the twentieth century. During the 1990's, potential techniques from other industries, such as manufacturing in construction (prefabrication), were adopted in construction industry to improve performance (Garnett and Pickrell, 2000). Construction-manufacturing relations were needed immediately after the Industrial Revolution and have been widely debated over the past few decades (Pan and Arif, 2011).

Various researchers (Gann, 1996; Egan, 1998; Blismas et al., 2006; and Nadim et al., 2011) have discussed about the learning phenomenon and knowledge transfer from other industries, especially from the manufacturing industry to achieve optimal results in construction industry. Off-Site Construction (OSC) is one such technology that was driven from the manufacturing industry. The manufacturing technology and its

processes seek to produce a greater number of different products while using a single systemised approach; this is also known as product flexibility. The ‘production’, instead of the ‘project’, approach of manufacturing allows the analysis and design of each phase of the production process in bringing maximum efficiency (Blismas et al., 2010). Kamar et al., 2009 stated that industrialization of construction industry can be observed all over the globe. In further sections, this research discusses about the concept of Off-Site Construction in detail.

2.2. Off-Site Construction

In simple terms, Off-Site Construction (OSC) is a different approach to the traditional construction methods. OSC can be understood as the manufacturing and prefabrication of building components and systems assembly away from site, perhaps in off-Site locations (Gibb, 2001; Pan et al., 2007; Arif and Egbu, 2010). Goodier and Gibb (2007) defined offsite as the manufacture and pre-assembly of components, elements or modules before installation into their final location. According to Gibb and Pendlebury (2006) Off-Site Construction refers to the part of the construction process that is carried out away from the building site, such as in factories or in specially created production facilities close to the construction site.

There are several arguments on the OSC methods, observations and adoption in the existing literature. Comparing pre-assembled building with a motor car is one amongst them. Mechanisation and robotisation of the construction process were the reasons for this comparison with car manufacturing industry (Gann, 1996). Gropius (cited in Gibb, 2001) has stated that “industrial production of complete buildings could be analogous with the mass production of the motor car”. Other arguments include: maximum OSC is always for the best; and standardisation means standard and therefore boring buildings (Gibb, 2001). On the other hand, Le Corbusier considered standardisation as philosophical, artistic and practical concept (Davies,2005). Pan and Sidwell, (2011) highlighted the dimension of introducing Off-Site Construction as an innovation attempt to improve the efficiency of construction in the UK.

According to research by Blismas et al., (2006), the uptake of OSC in construction is limited, despite the well documented benefits. One of the major reasons behind this was

the reluctance among the clients and contractors to adopt OSC, since it was difficult to realise and understand the benefits of OSC. Previous research has also highlighted the poor understanding of OSC application and usage among stakeholders. As documented by Blismas et al. (2006), some have considered this approach as too expensive to justify its use, whilst others have pursued OSC as the panacea to the construction industry's manifold problems (Gibb, 2001).

Vernikos et. al., (2012) have explained that OSC was not often considered in the maritime, bridges and tunnelling sub-sectors. The same research has also highlighted the scope for OSC practice in the emerging sub-sectors, such as bridges, water and environment management. According to these authors, the bridges have greater potential because they have great scope for repetitive forms or sections, which are significant in the OSC process (Vernikos et al., 2013).

2.3. OSC Related Terms

The other terms in use for OSC, include Off-site Production (OSP), Off-site Fabrication (OSF), Off-site Manufacturing (OSM), Off-site Construction (OSC), pre-assembly and prefabrication. (Goodier and Gibb, 2007). Manufactured construction, Off-site manufacturing and modern methods of construction are some terms used interchangeably in the literature (Arif et. al., 2010). The "build offsite" Glossary of Terms defined OSP, as methods which provide an efficient product management process to provide more products of better quality in less time. (Buildoffsite, 2012).

Several terms have been used to describe OSC: Modern Methods of Construction (MMC), prefabrication, pre-assembly, manufacturing in construction, offsite fabrication, modular construction, Industrial Building Systems (IBS), Standardisation and pre-assembly, Offsite Manufacturing (OSM) are some of the terms used synonymously in the literature (Gibb and Isack, 2003, Badir et al., 2002, Arif and Egbu, 2010). There are arguments in the OSC literature as to whether to call it as a product, process or a system (Kamar et al., 2011a). Table 2.1 below provides various terminologies for OSC. Although the terminology differs in various countries, attention towards OSC is significant globally. It is widely known as Off-Site Construction

Techniques (OSCT) in the US, Modern Methods of Construction (MMC) in the UK, Offsite Manufacturing (OSM) in Australia and Industrialised Building Systems (IBS) in Malaysia. According to Ngowi et al. (2005), new thinking towards construction materials, creative and innovative technologies can ease the adoption of offsite techniques. On the other hand, Azman et al. (2010) have pointed the differences in adoption due to local conditions._In the UK, Off-Site manufacturing has been 're-branded' broadly within the term "Modern Methods of Construction" (MMC). Gibb (1999) stated that Modern Methods of Construction is the term used by the UK government to describe multiple innovations in house building, most of which are offsite technologies. Further it also includes innovative onsite based methods. In simple terms, MMC embraces a number of approaches involving off-site manufacturing or assembly (NHBC,2016). Offsite MMC are prefabrication elements or parts constructed in factory, then transported and assembled on site. On the other hand onsite MMC refers to building blocks and parts of structures takes place directly on site (Kyjaková et al., 2014). Thus, it is clear that OSC is a sub-set of Modern Methods of Construction (MMC). Hence, it can be said that, OSC falls under MMC but all MMC are not OSC.

Table.2.1 Categorisation of terminology

Terminology	Category term
OS	Off-Site Production (OSP)
	Off-Site Manufacturing (OSM)
	Off-Site Fabrication (OSF)
	Off-Site Construction (OSC)
PRE	Pre-assembly
	Prefabrication
	Prefab
MM	Modern Methods of Construction (MMC)
	Modern Methods of House Construction
	Modern Methods of House Building
Building	System Building
	Non-traditional Building
	Industrialised Building

Source: Pan (2006)

2.4. Types of OSC

Gibb and Isaac (2003) have listed four major types of OSC that are extensive in practice. These include Panellised system, Modular/Volumetric system, component/Non volumetric system and Modular systems. In addition, Arif and Egbu (2010) have referred to the new category of OSC as a combination of any two or more volumetric or non volumetric systems, named as Hybrid systems. Table 2.2 describes various levels of offsite with definitions and examples. OSC is implemented in diverse types of construction projects. Even the nature of the construction industry is complex, as OSC can be implemented in many types of projects. Some of the areas are public/social housing, private housing, offices, hospitals/health, retail, schools, university/research, student accommodation, factories/warehousing, hotels/leisure, restaurants/fast food, supermarkets and defence construction (Goodier and Gibb, 2007). However, the adoption of Offsite techniques is influenced by the type of project and the construction application.

The Off-Site Construction industry and systems vary with the degree of adoption of technology and standardisation (Azman et al., 2010). Azman et al. (2010) have identified that Malaysia is currently at the stage of hybridisation system i.e. the initial stage setup while US, UK and Australia have already achieved the standard systems (Azman et al., 2010).

Table 2.2: Levels of offsite - Definitions and examples

Category	Definition	Example
Component manufacture & sub-assembly	Items always made in a factory and never considered for on- site production	Wood kits, Metal building
Non- volumetric pre- assembly	Pre-assembled units which do not enclose usable space	Timber roof trusses
Volumetric pre-assembly	Pre-assembled units which enclose usable space and are typically fully factory finished internally, but do	Toilet and bathroom pods

	not form the buildings structure	
Modular Systems	Pre-assembled volumetric units which also form the actual structure and fabric of the building	Prison cell units or hotel/ motel rooms
Hybrid system	Consists of a combination of any two or more volumetric or non-volumetric systems.	Extensively used in commercial and residential buildings

Source: Gibb and Isack (2003) and Arif and Egbu (2010)

Furthermore, Langdon and Everest (2004) have reported that panellised systems can be categorised as open and closed panels. UK residential construction utilises these systems in high number (Gibb and Isack, 2003). The extent of prefabrication that the Hong Kong Housing Authority has adopted lies between non-volumetric and volumetric pre-assembly (Chiang et. al., 2006). According to Vernikos et al. (2012), the appreciation and adoption of Off-Site Systems varies greatly within the sub-sectors. The same research further states that special concentration on the individual needs of the market would enable efficient up-gradation, despite the segmentation of the construction industry. Table 2.3 below provides the categorisation of Off-Site systems in various countries.

Table 2.3: Categorisation of Off-Site systems in various countries

No	Country	Categorization of Off-Site system	Author
1	USA	Offsite pre-assembly	Lu (2009)
		Panellized system	
		Modular Building	
		Hybrid system	
2	UK	Component manufacture & sub-assembly	Goodier and Gibb (2005)
		Non- volumetric pre-assembly	
		Volumetric pre-assembly	

		Modular Building	
3	Australia	Non- volumetric pre-assembly	Blismas and Wakefield (2009)
		Volumetric pre-assembly	
		Modular Building	
4	Malaysia	Pre-cast concrete systems	IBS Info (2010)
		Formworks systems	
		Steel framing systems	
		Prefabricated timber framing systems	
		Block work systems	
		Innovative product systems	

Source: Azman et al. (2010).

2.5. Benefits of Off-Site construction

As mentioned earlier, there are many advantages associated with the adoption of OSC. It is acclaimed worldwide for being cost effective, productive and quality oriented. Aldridge et. al., (2001) have documented the benefits of pre-assembly and standardisation for construction projects through all the stages, right from feasibility to design and construction, handover, operation and decommissioning. Their research has classified the benefits of pre-assembly and standardisation. Aldridge et al., 2001 argued that some benefits from offsite were measurable in monetary or non-monetary terms, while other benefits that have influenced the success of the project or business were not easily measurable. Blismas et al., (2006) resonated with similar opinion and stressed the need for holistic and methodical assessments of the applicability and overall benefit of OSC solutions in a particular project context.

Some of the benefits observed from literature were quick construction/shorter project duration, reduction in cost, improved quality and control, better onsite safety due to closed manufacturing environment, reduction in time and risk factors, reduced labour and higher tolerance and waste minimisation. (Gibb and Isack, 2003; Jaillon and Poon, 2010; CRC, 2007; Goodier and Gibb, 2007). Blismas et al. (2006) have supported the advantages of offsite practices in terms of time, quality, cost, productivity, people/manpower and process. The study conducted by Arif et al. (2012b) has

demonstrated that the OSC techniques have minimised construction waste. Figure.2.2 illustrates the benefits of OSC under the process; Cost/Value/Productivity improvement; Quality improvement; and improved logistics and site operations.

The benefits of OSC are highly dependent on project-specific conditions and combination of building system/methods adopted in the project. However, decisions regarding the OSC application are unclear and complex in most cases. A pilot study by Pasquire and Gibb (2002) have identified that there is no rigorous data due to the lack of formal measurement procedures or strategies in the OSC. Hence, the decisions on OSC usage are largely based on the subjective evidence (Blismas et al., 2006). Hamid and Kamar (2012) have discussed about environmental impact, ease of construction, construction time saving and construction waste management. CABE (2004) demonstrated that OSC may be treated as a "realistic" means to improve quality, reduce the time spent on-site, and improve site safety and to address skill shortages. Tam et al., (2007) have identified prefabrication as a panacea for waste minimisation after interviewing professionals in the Hong Kong construction sector.

OSC methods significantly contribute to the sustainable built environment. Kamali and Hewage (2017) presented modular construction as one of the primary methods to be used for sustainable construction. Pan and Arif (2011) found that OSC significantly addressed the environmental dimension of sustainability through reduction of waste; the economic dimension through mass customization and the social dimension by providing better and safer working conditions. In a study on Malaysian construction industry, Musa et al., (2014) explained that the Modular Industrial Building systems encourage the sustainable construction process through producing less waste, reducing damage towards the environment and ecosystems, causing less air and sound pollution, providing safer work environment.

Although the benefits are largely identified in literature, there are also some arguments associated with OSC. For instance, Goodier and Gibb (2007) have observed differing opinions among the construction practitioners in the UK regarding the benefits of OSC.

The same research also documented that the current uptake of OSC in construction is limited despite overwhelming benefits. However, Blismas et al. (2005) have mentioned that the benefits of OSC are highly influenced by project conditions and the combination of building methods used.

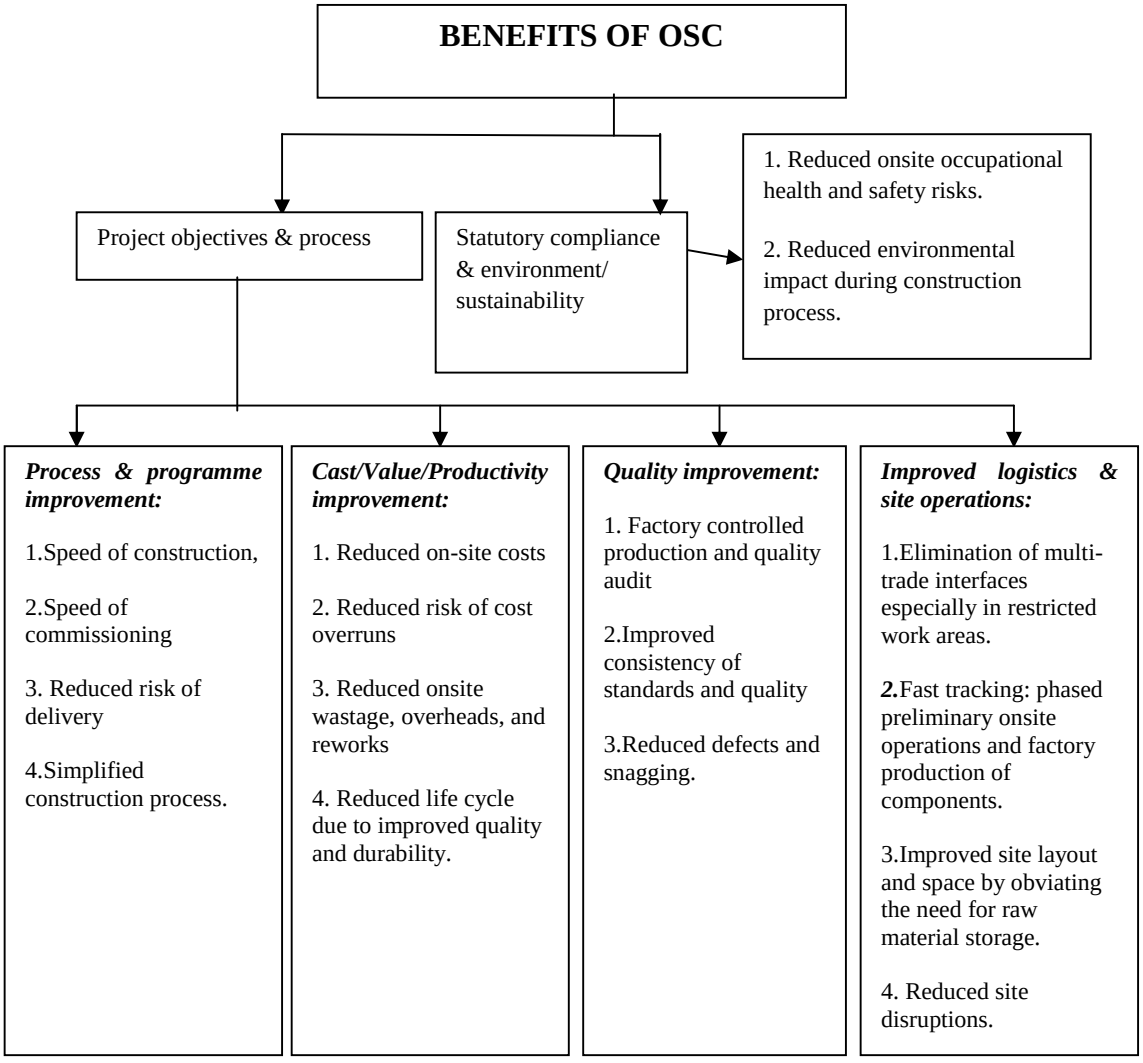


Figure. 2.2 Benefits of Off-Site construction. Source: CRC (2007)

2.6. Factors Influencing Off-Site Construction

From the thorough literature review and comprehensive comparisons between offsite and on-site construction methods, the researcher has identified around thirty factors that influence the adoption of OSC methods. A detailed list is provided in Table 2.5.

Various researchers have established relevant grouping and investigated the impact of these attributes in their respective research contexts. Chen et. al., (2010) research was conducted through grouping the attributes into seven dimensions that are associated with economic, social and environmental issues (Table 2.4). These are:

1. Long-term cost (economic): Costs associated with long-term building issues such as durability, maintenance cost and life cycle costs;
2. Constructability (economic): The extent to which a design facilitates efficient use of construction resources, which can be reflected by lead time, construction time, integration of supply chains, integration of building services etc.;
3. Quality (economic): The perception of the degree to which the building meets the building team's expectations;
4. First cost (economic): Costs associated with preconstruction and construction, such as material costs and labour costs;
5. Impact on health and community (social): The impact of on-site construction activities on workers' health and safety and surrounding local communities, including the influence on future occupants' health;
6. Architectural impact (social): The influence on physical space, decorative finishes, architectural look, etc.;
7. Environmental impact (environmental): The influence on environment including site disruption, material consumption, energy use, waste production, pollution generation, etc.

Table 2.4: List of Attributes and Sub-Attributes identified by Chen et al. (2010)

Attributes	**Sub-attributes**
1.Project characteristics	1.1 Cost constraints
	1.2 Time constraints
	1.3 Quality constraints
	1.4 Repeatability
2. Site conditions	2.1 Site issues (site access, storage area, etc.)

	2.2 Anticipated climatic conditions during construction
3.Market attributes	3.1 Availability of the local prefab firms
	3.2 Availability of qualified workers
	3.3 Availability of equipment for installation
4.Local regulations	4.1 Workers' health and safety considerations
	4.2 Waste and environmental pollution considerations
	4.3 Permission and limitation of prefabrication elements transportation (delivery logistics)

Similarly, Goulding et al., (2012) have investigated the state of offsite, current needs and challenges in terms of three core sectors of the construction industry i.e. Process, Technology and People. Further, it examined each indicator within the three boundaries of Design, manufacturing and construction (Figure 2.3). This grouping enabled the researchers to establish the status quo of each area in their respective variables. For instance, the status of the core area design was investigated in terms of Design – People, Design – Process, Design – Technology. Further, Goulding et al., (2012) has developed strategies and recommendations for each individual core area for three different time spans: short term (0-5 years), medium term (6-10 years) and long term (beyond 10 years).

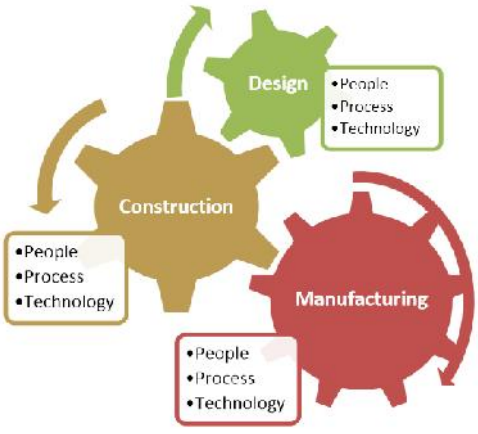


Figure 2.3 Identified core areas of Off-Site Construction (Source: Goulding and Arif (2013)

The implementation decision of offsite is influenced by factors such as location, land use, density, volume, user needs, labour and environmental conditions (Badir et al., 2002; Gibb and Isack, 2003). Venables et al. (2004) have conducted research through interview analysis with 27 key players in both manufacturing and housing development. The study found that the uptake of Off-Site Construction was partly influenced by the perceptions of developers with regard to its advantages and disadvantages. Cultural shift, incentives, cost, time and quality attributes could be adopted for the Indian context.

Mesároš and Mandičák (2015) have considered mass production, flow production, production equipment, site equipment, construction time, modular coordination, integration and transportation as the factors influencing the successful application of Modern Methods of Construction. Furthermore, the factors influencing offsite uptake in the infrastructure projects have been investigated by Vernikos et al., (2011). This research has identified that the influencing factors for maritime, bridges and tunnelling sub-sectors include geography, geomorphology, local perception of risk, technological capacities, material and labour costs and procurement systems. Cooperation amongst key stakeholders is another major issue. Several researchers (Horman et al., 2005; Ding, 2008; and Jaillon and Poon, 2010 highlighted the need for early collaboration amongst the stakeholders for effective implementation of OSC techniques. Further, this should reflect in the process as a continuous practice throughout the construction, operation and maintenance of the building.

Table 2.5: Factors Influencing Off-Site Construction

Factors	**Author**
Construction time (speed in construction)	Jaillon and Poon (2008) , Pan et al (2008), Lessing (2006), Oostra and Johnson (2007), Blismas (2007), Mesároš and Mandičák (2015)
Maintenance and operation costs / Disposal costs / Life cycle costs / Initial construction costs / Material costs / Labour cost	Chen et al. (2010), Tam et al. (2007), Blismas and Wakefield (2007)
Speed of return on investment	Chen et al. (2010)

Project planning and control / Project programme and scheduling	Pan et al (2008), Lessing (2006) and, Ahmad (2005)
Production process / Lead-times / Process coordination / (to name few: Lean and Just in time approaches)	Chen et al. (2010), Haas and Fangerlund (2002), Li (2006), Gibb (1999) and Lessing (2006)
Early decision making to use offsite/ Early involvement of project team/ Design stage adoption	Gibb (1999), Blismas (2007), Pan et al (2008), and Buildoffsite (2008), Song et al. (2005)
Integration of building services	Chen et al. (2010)
Procurement System (or) strategy / Partnering / Integration of supply chains/ Management supply chain	Blismas and Wakefield (2007), Pan et al (2007), Pan et al (2008), Whelan (2008) and Malik (2006), Kamar et al (2009), National Audit Office Report (2005), Pan et al (2007), Malik (2006), Lessing et al (2005), and Gibb (1999)
Training/ Experience and competent workforce	Goodier and Gibb (2007), Gibb (1999), Nawi et al (2006), Ogden (2005)
Working collaboration / Communication and information flow	Pan et al (2007),Haas and Fangerlund (2002), Blismas (2007), Pan et al (2008) and, Haas and Fangerlund (2002)
Working conditions / Inclusive environment	Song et al. (2005), Shen et al. (2007)
Risk Management / Workers' health and safety	Chen et al. (2010), Kamar et al (2009) and Hassim et al (2009)
Aesthetic options | Design / Design standard and project function	Tam et al. (2007), Song et al. (2005)
Standardisation	Gibb and Isack (2001), Pan et al (2008), Haas and Fangerlund (2002)
Constructability	Chen et al. (2010)
Usage efficiency	Soetanto et al. (2004)
Adaptability and flexibility	Gibb and Isack (2001)
Disaster preparedness / Futuristic	Kim et al. (2009)
Durability	Chen et al. (2010)
Defects and damages	Chen et al. (2010)
Technology (Machinery and equipment)	Blismas and Wakefield (2007)

Information and Communication Technology (ICT)	Eichert and Kazi (2007) and Gibb (1999)
Material consumption	Jaillon and Poon (2008)
Waste generation and disposal / Recyclable/renewable contents (elements)	Jaillon and Poon (2008), Chen et al. (2010) , Song et al. (2005)
Site attributes/ Site disruption, Transportation and lifting	Chen et al. (2010), Song et al. (2005)
Local conditions / Transportation and infrastructure/ Traffic congestion / Road network	Chen et al. (2010), Blismas and Wakefield (2007), Pan et al (2008)
Governance / Policy and strategy match / Project control guidelines / Integrated environmental and economic program / Business planning and process/ Continues improvement / Principles and values / Vision and corporate motivation	Tam et al. (2007), Song et al. (2005), Pan et al (2008), Pan et al (2005), Ian et al. (2008), Kamar et al (2009), Pasquire and Connolly (2002)
Legislation / Understanding on building regulations	Song et al. (2005), Pan et al (2008)
Public awareness / Promotion	Abd Hamid and Mohamad Kamar (2011)
Local economy / Influence on job market	Chen et al. (2010), Song et al. (2005)

2.7. Drivers towards the adoption of OSC

Numerous studies have explored the advantages of using Off-Site Construction methods. In this research, the term ‘driver’ is defined as the factor that positively affects the adoption of offsite techniques in construction activities. As discussed in the section above, several factors were documented in the existing literature. The two fundamental drivers for OSC are, ‘pragmatism’ and ‘perception’ (Gibb ,2001). Further, Gibb (2001) explained about pragmatism as the ‘industry response to an urgent need combined with a lack of resource’ and perception as the ‘client and public reaction to a prevailing design philosophy’. According to Gibb (2001), industry response to an urgent need varies from country to country and from time to time. The same research has also pointed that client and public perception of design has changed to place the emphasis on achieving value for money, zero defects, minimal waste and environmental impact.

Among these, cost certainty, time certainty, high quality achievement, reduction in health and safety risks, incentives from local authorities, good transport network and demand for housing are considered as drivers for the adoption of OSC.

Taylor et al. (2004) have highlighted speed in construction as a major drive for Off-Site Construction. They stated that the majority of the contractors have used MMC for speed. In countries like China and Malaysia, extensive promotion, incentives and skills shortage have encouraged OSC adoption (Arif and Egbu, 2010; Kamar et al., 2009). According to Pan et al. (2007), the drivers for using offsite were: assurance of cost and time certainty; minimising onsite duration; achieving high quality; reducing health and safety risks; reducing some environmental impacts during construction; maximising environmental performance during the life cycle; restricted site specifications; addressing skill shortages; government promotion; revisions to building regulations; and the client's influence. Blismas et al. (2005) have documented further grouping in the drivers under cost, time, quality, health and safety and sustainability issues. Table 2.6, provided below, lists the numerous drivers identified from the literature in the field of Off-Site construction.

Table.2.6. Drivers identified from various studies in the field of Off-Site construction

Author	**Drivers**
Goodier and Gibb, (2007)	Decreased construction time, Increased quality, More consistent product, Reduced snagging and defects, Increased value, Increased sustainability, Reduced initial cost, Reduced whole life cost, Increased flexibility, Greater customization options, Increased component life
Pan. et. al., (2007)	Ensuring cost certainty, Ensuring time certainty, Minimizing onsite duration, Achieving high quality, Reducing health and safety risks, Reducing environmental impact during construction, Maximizing environmental performance during lifecycle, Restricted site specifics, Addressing skill shortages, Government promotion, Revisions to Building Regulations, Client's influences

Blismas and Wakefield (2009)	Skills, Process and programme, Environmental sustainability, Operational Health & Safety risks, Cost, value and productivity, Quality, People and work conditions, Industry and market culture, Industry knowledge, Logistics and site operations, Regulations, Supply and procurement.
Blismas et al., (2005)	**Cost Drivers:** Ensuring project cost certainty, Minimising non construction costs, Minimising construction costs, Minimising overall life cycle costs. **Time Drivers:** Ensuring project completion date is certain, Minimising on-site duration, Reduction in overall project time. **Quality Drivers:** Achieving high quality, Achieving predictability of quality, Achieving performance predictability throughout the lifecycle of the facility **Health and Safety Driver:** Reducing health and safety risks **Sustainability Drivers:** Reducing environmental impact during construction, Maximising environmental performance throughout the lifecycle.
Becker, (2005) cited in Shahzad (2011)	Speed of construction, cost certainty or minimizing remedial and onsite costs, quality failure of traditional onsite methods, move towards weather resistance, better performing and better quality building, review of contractual relationships following litigation, lack of onsite operative skills, focus on safety of building occupants due to structural failures, health and safety.

Speed of Construction / Time: Many researchers highlighted that application of OSC methods significantly speed up the construction process. According to Buildoffsite (2013), OSC methods contribute up to 60% of faster construction over conventional construction methods. Thus, speed of construction plays as a key driver to adopt OSC methods in construction industry.

Cost: Similar to the speed of construction, the cost factor associated with the application of OSC methods was greatly acknowledged by several researchers. Blismas et al., (2005) and Pan et al., (2007) have discussed about the impact of the benefits such as ensuring cost certainty, minimising construction and non construction costs, and minimising overall life cycle cost that are obtainable from the adoption of OSC techniques influence the key players in the industry towards the adoption of OSC methods.

2.8. Barriers towards the adoption of OSC

In order to promote OSC, it is essential to know the barriers constraining the adoption of OSC techniques in construction. Numerous barriers from various nations have been documented in literature. Several studies have explored the status of OSC and investigated the influencing factors. For instance, barriers against OSC in U.S. have been documented in the MBI (2010) report. These include building code, regulatory (regulations such as permits, fees, and zoning), legislative, and legal barriers. Similarly, Goodier and Gibb (2007) have presented barriers in the UK construction industry, while Tam et. al., (2007) have reported constraints in the context of Hong Kong.

Arif and Egbu (2010) stated that numerous factors such as economic, environmental, social context and peoples' perspectives influence the stature of OSC in any given nation. However, some of the barriers may prevail in other countries. For instance, researchers (Pan et al., 2007, Pan and Sidwell, 2011) perceived large initial capital as an economic barrier towards the uptake of OSC in the UK. But, China, being the manufacturing power house (Arif and Egbu, 2010) had addressed this barrier through achieving economies of scale. Pan et al. (2008) stated that interfacing problems during both erection and execution have inhibited a wider take-up of Off-Site Construction technology.

While offsite is pursued as an innovation in construction, the study conducted by the Housing Forum (2001) has documented the barriers to innovation in construction industry. This report has highlighted the barriers which clients, contractors, house builders and developers, consultants and suppliers have confronted on a daily basis at organisational level and at site level. Research by Pan et al. (2007) has documented a

list of barriers in offsite adoption among the UK house builders. According to them, the barriers include complex interfacing between the systems, inability to freeze the design early, site constraints and logistics, higher capital cost, difficult of achieving economies of scale, risk averse culture, client scepticism, attitudinal barriers due to historic failures, reluctance to innovate, skill shortages, fragmented industry structure, lack of long-term cooperation between project teams. Other factors include the nature of the UK planning system, manufacturing capacity, unfavourable organisational mechanisms, lack of previous experience, importance of land acquisition in house building business and legal issues. High initial investment and wages for skilled labour were also identified as major barriers towards the acceptance of IBS (Industrial Building System) in the construction industry in Malaysia (Hamzah et. al., 2010).

A recent study conducted in China has revealed that cultural shifts are a major challenge to OSC uptake, since it is difficult to shift peoples' mind-sets from traditional construction practices (Arif and Egbu, 2010; Kamar et al., 2009). Gibb (2001) has looked into history through Gropius (1959) and identified an evergreen struggle in dealing with standardisation against uniformity and variation, maximisation and flexibility. Longer lead-in times when compared to traditional construction methods, were also identified as a significant barrier, especially to contractors (Goodier and Gibb, 2007). Previous studies by Venables et al., (2004), Pan et al., (2007) and Zhai et al., (2014) have also documented the role of long lead-in time as an impeding factor to the greater uptake of OSC. The Provisional Construction Industry Coordination Board (PCICB), which has been set up to implement the recommendations of the CIRC in Hong Kong, observed that "despite an increasing tendency among civil engineering contractors to make use of prefabricated components, up-front investment remained an obstacle to unleash its full cost-saving potential" (PCICB, 2004). Research by Aldridge et al. (2001) has highlighted the interesting factor, "Pay Back".

Edge et al. (2002) have found that house buyers are so strongly influenced by negative perceptions of the post-War 'prefab'. Adding to this, Pan et al. (2007) have documented the resistance from the house builders in the UK towards any innovation in house construction that affect the image of 'traditional' house. The human perception barrier

in offsite practices also exists among architects and other designers (Pan et al., 2004). The list of barriers identified from the literature is provided in Table 2.7 below.

Table 2.7 Barriers identified from various studies in the field of Off-Site construction

Author	Barriers
Goodier and Gibb, (2007)	More expensive, Longer lead-in times, Client resistance, Lack of guidance and info, Increased risk, Few codes/standards available, Negative image, Not locally available, No personal experience of use, Obtaining finance, Insufficient worker skills, Reduced quality, Restrictive regulations.
Pan. et. al., (2007)	Complex interfacing between systems, Unable to freeze the design early on, Site constraints and logistics, Higher capital cost, Difficult to achieve economies of scale, Risk averse culture, Client scepticism, Attitudinal barriers due to historic failures, Reluctance to innovation, Skills shortage, Fragmented industry structure, Lack of long-term cooperation between project teams, Nature of the planning system, Manufacturing capacity, Unfavourable organizational mechanism, lack of previous experience,
Blismas and Wakefield (2009)	People and work conditions, Industry knowledge, Cost, value and productivity, Industry and market culture, Process and programme, Skills, Quality, Supply and procurement, Regulations, Logistics and site operations, Operational Health & Safety risks, Environmental sustainability
Blismas et al., (2005)	**Site barriers:** Restricted site layout or space; Multi trade interfaces in restricted work areas; Limited or very expensive available skilled on site labour; the problem transporting manufactured products to site; Live working environment limits site operation, Limitation to movement of OSP units around site, Site restricted by external parties

	Process barriers: Short overall project time scales, Unable to freeze design early enough to suite OSP, Limited capacity of suppliers , Not possible for follow-on projects to use the same processes, **Procurement barriers:** Project team members have no previous experience of OSP, Obliged to work with a particular supply chain , Not willing to commit to a single point supplier, Obliged to accept lowest cost rather than best value, Key decisions already made preclude OSP approach, Limited expertise in Off-Site inspection, Obliged to accept element costing, Early construction/manufacturing expertise & advice unavailable
Becker, (2005) cited in Shahzad (2011)	Process and programme; cost, value and productivity; regulations; industry and market culture; supply chain and procurement; skills and knowledge; logistics and site operations

2.9. Critical Success Factors (CSF's) of Off-Site Construction

Following the review of major challenges, drivers and barriers for the adoption of Off-Site Construction practices, this section explores Critical Success Factors (CSF) with regard to OSC. The practitioners have to implement offsite techniques through identifying the factors that are critical for success. Kamar, Hamid and Alshawi (2010) have highlighted the importance of pre-planning, coordination, effective communication, involvement in design, experienced staff, decision making, improved procurement and contracting, supply chain management, partnering, business strategy and Information and Communication Technology (ICT) in successful adoption of IBS in Malaysia.

New concept such as BIM (Building Information Modeling) has evolved as a major tool to accelerate the current practice of OSC techniques and also address some of the challenges associated. Goulding and Arif (2013) have stated that BIM align more naturally with OSC. The same research also pointed that OSC stands at the intersection of lean manufacturing techniques, sustainable building practices, and advances in the adoption of BIM. This stresses the role of BIM in the practice of OSC techniques in

construction industry. In this context, current research attempts to understand the concept of BIM.

National BIM Standard (NBIMS) defined BIM as a digital representation of physical and functional characteristics of a facility. Eastman and Sacks (2008) have explained about BIM as the technology that allows construction data to be 'machine readable' and enables manufacturing of components without human intervention possible. According to Fraser et al., (2015), BIM is used to generate and mange data throughout the entire life cycle of the building. The digital model created through this software contains the physical attributes of the project along with the data of time, cost and quantities. Hence, it enables better collaboration and coordination between the project team, clients and end users. Eastman et al., (2011) argued that BIM extensively supports the sub-contractors and fabricators in the whole process of design development, detailing and integration. In addition to the short term impact on productivity and quality, BIM enables fundamental process changes through providing essential information for mass customisation (Womack and Jones, 2003 cited by Eastman et al., 2011, P. 307). Fraser et al., (2015) documented the benefits of implementing BIM in OSC projects. These include, reduced risk through improved co-ordination, control and flow of information, improved accuracy of cost and programme planning, increased productivity efficiency and predictability and reduced rework onsite. BIM can be used in OSC projects to capture 3D scans of the in-situ works prior to the interfacing with offsite elements, simulate and assess the performance of a design, validate logistics and maintenance access, simulate the assembly and installation processes, simulate the commissioning process (Fraser et al., 2015).

Based on a literature review, Kamar et al. (2010) have identified factors that reflect positive results in the IBS projects. These include:

- **Good working collaboration:** This will solve the problems related to complex interfacing between systems and ensure efficient process in both manufacturing plants and on-site (Pan et al., 2007; Lu and Liska, 2008; Haas and Fangerlund, 2002).

- **Effective communication channel:** Effective communication across the supply chain needs to be established in order to coordinate the process and deal with critical scheduling from the beginning until the project completion (Pan et al, 2008; Blismas, 2007)
- **Continuous improvement and learning:** Successful implementation of OSC depends on organisational ability to expedite the learning curve from one project to another (Neala et al., 1993). Therefore, continuous improvement and learning is a critical success factor.
- **Coordination of design, manufacture, transportation, and installation:** Coordination in the process is vital for the success of IBS (Haas and Fangerlund, 2002).
- **Early decision making:** Key decisions on strategy, application, design, logistic and detail unit should be made at the earliest for Off-Site projects (Gibb, 1999). Blismas et al. (2006) have warned against using OSC as an afterthought, or as a late solution to shorten construction time. Rather it should be used as an integral part of the design from the earliest possible stage of the project (Gibb, 1999).
- **Involving team members at the early stages:** The team members should be involved during the design stages to ensure that the design is not taken to a stage where it restricts the benefits that can be brought through the use of this method (Pan et al., 2008; Blismas, 2007; Gibb, 2001).
- **Team building with experienced workforce:** Successful implementation requires an experienced workforce and technical capable in design, planning, organising and controlling function with respect to production, coordination and distribution of components.
- **Information and Communication Technology (ICT):** ICT is a vital and reliable support tool to improve tendering, planning, monitoring, distribution, logistic and cost comparison process by establishing integration, accurate data and effective dealing with project documents (Eichert and Kazi, 2007; Hervas and Ruiz, 2007).
- **Integrated supply chain:** Successful implementation of OSC requires partnership and close relationship with suppliers and sub-contractors from the

early stage of the project process (Kamar et al., 2009; Pan et al., 2008; Pan et al., 2007).

- **Extensive planning and scheduling:** Good planning and scheduling of activities in advance is critical. This leads to better project performance, coordination, better scope control and ensures a smooth project sequence (Haas and Fangerlund, 2002).
- **Improved procurement strategy:** Improvement in procurement strategy and contracting is important to achieve long term success (Pan et al., 2007 and Pan et al., 2008). The negotiations, procurement and contract should each allow the contractors and manufactures to contribute their knowledge, experience of design, planning and construction of the building.
- **Risk Management strategy:** Planning and addressing risks is an important factor in dealing with offsite practices. Contingency measures can be planned by assessing the potential cause of delays and disruption at every stage of the supply chain.
- **Process standardisation:** This requires emphasis on design and process standardisation and more effective use of the concept of repetition. The design and illustration of products are documented in systematic ways to ensure that everything is repeated in the same manner for installation (Kamar et al., 2009).
- **Supply chain and logistics management:** High demands will be raised on the management of supply chain and logistic activities (Lessing et al 2005). This needs to be coordinated in a manner that allows the contractors to gain full control of the process with the intention of improving efficiency and competitiveness.
- **Corporate motivation:** Successful implementation of OSC also depends on 'top-down' commitment and corporate motivation. This in return will ensure the right motivation and commitment from the whole team (Blismas et. al., 2007).
- **Business approach:** Management needs to establish clear business need in offsite and build strategic plan around it, including effective combination of cost and production knowledge (Blismas et al., 2006).

2.10. Global trends in OSC

The move towards Modern Methods of Construction (MMC) and manufacturing in the construction industry is a global phenomenon. Many studies and research findings have documented the magnitude of OSC adoption and trends in various countries. This section discusses the vital findings from the literature. Off-Site Construction is being considered as an efficient alternative, as it addresses important issues in construction and infrastructure projects. In recent decades, this trend has increased significantly in many countries. Though developed nations (for instance, the UK, US, Australia and Japan) have given it wider acceptance, middle income developing nations are taking steps towards OSC in order to achieve competitive advantage in the industry (Arif et al., 2012).

Extensive research and implementation of OSC have been identified in the UK. The UK industry and official organisations have already started prioritising OSC under the brand of Modern Methods of Construction (MMC). This method of construction gained momentum after the 'Rethinking Construction' report by Egan (1998), along with other government and private research groups' recommendations to address the under-achievement in construction (Gibb and Isack, 2003; Badir et al. 2002; Kamar et al, 2009; Arif and Egbu, 2010). Taylor's research (2010) reported an average increase of over 10% in the market share of Off-Site Manufacturing (OSM) in the UK between 1998 and 2008. However, various researchers (Venables et al., 2004; Goodier and Gibb, 2005; and Taylor, 2010) have highlighted the lack of standard method of calculation for the market valuation of the OSC sector in the UK. TheUK government policies and the Egan report played a vital role in the implementation of prefabrication in the UK construction industry. However, despite the extensive promotion, a study by Goodier and Gibb (2007) identified that the usage of OSM formed only 2.1% of the overall UK construction industry. This indicates that various barriers are hindering the rapid uptake of OSM, even in the UK. Similarly to the recommendations in the UK, the Committee on Advancing the Competitiveness and Productivity of the US Construction Industry (CACPUCI, 2009) considered the application of OSC technology as one of the five key recommendations to improve the efficiency and productivity of the US construction industry (cited in Shahzad, 2011). In the US, this trend of using OSC has been well

received in industrial projects, in comparison with commercial and infrastructure projects (Azman et al., 2010). According to the Modular Building Institute (MBI), the shortage of skilled labour and lack of enthusiastic new players are challenging the current US construction industry. However, consumer appreciation for fast-track products with greater quality and safety compliance is driving OSC uptake in the US (MBI, 2010).

The Malaysian government and Construction Industry Development Board (CIDB) are working vigorously to implement OSC techniques in the construction sector. The government's policies under the seventh Malaysian plan have increased the adoption of OSC methods in the Malaysian construction industry. According to this plan, the construction industry must use pre-fab or manufactured materials in two-thirds of its construction activities, in terms of the policy administration of new technologies. Such a technological shift towards IBS in Malaysia is exemplary (Badir et al., 2002). In a vision document entitled 'Construction-2020', the Australian construction industry considered OSC to be a key factor to improve the property and construction industry in the near future (cited in Goulding et al., 2012b). The same research has also established close observations on the global existence and acceptance of OSC. As cited in this study, Sekisui Homes is producing 70,000 manufactured homes per year in Japan. Japan has the highest amount of OSM practice in the world (Goulding et al., 2012b).

Developing nations like China, Malaysia and Hong Kong have successfully implemented off-site techniques. Arif and Egbu (2010) highlighted the potential of OSC in meeting the housing needs of China. They also explored the scope of off-site practices in China, and identified China as a manufacturing powerhouse. Similarly, Hong Kong has also implemented prefabrication methods religiously. The majority of the OSC usage can be observed in the public housing projects implemented by the housing authority of Hong Kong. Jaillon and Poon (2008) highlighted the fact that Hong Kong's practice of OSC has resulted in a 52% reduction in construction waste through implementing OSC techniques. This is a significant contribution towards waste minimization, which is one of the benefits of OSC.

The uptake of OSC varies considerably from country to country (Goulding and Arif, 2013). However, for the Indian context, the UK and Malaysian industries' trends and promotion of implementing OSC will be observed closely, while considering the experiences of other nations.

2.10.1. United Kingdom

In the UK, rising housing demand, and schedule and cost overruns are challenging the construction industry, along with a skills shortage and skill gaps (Pan & Sidwell, 2011; Taylor, 2010; Pan et al., 2007; Nadim and Goulding, 2010). The industry has been severely criticised for its performance. There has been constant pressure on the industry to achieve greater productivity and improved quality. The skill shortages and skill gaps in the construction industry at different organisational levels have been repeatedly discussed by various researchers (Goodier and Gibb, 2005; Taylor, 2010; Arif, 2012; Khalfan et. al., 2008; Alshawi et al., 2009). Further, many initiatives were introduced to improve the performance and image of the construction industry. These initiatives included encouraging new ways of working, thinking and learning from other industries (Mullens and Arif, 2006; Gann, 1996; Pan & Arif, 2011a). The UK Interdepartmental Committee on House Construction was initiated to develop alternative construction materials and methods in order to improve efficiency, economy, and speed of construction (Waskett, 2001). OSC was highly considered as a viable approach for delivering high-quality innovative solutions with cutting-edge design (Rahman, 2013).

Off-Site Manufacturing (OSM), Standardisation and Pre-assembly (S&P), Prefabrication (Prefab) and Off-Site Production (OSP) were used interchangeably under the term MMC in the existing literature (Pan, Gibb & Dainty, 2008; Arif and Egbu, 2010; Nadim and Goulding, 2010). In the UK, Off-Site Construction is considered under Modern Methods of Construction (MMC), which was one of the recommended solutions for the above-mentioned problems in the construction industry in the UK. Goulding and Arif (2013) stated that MMC has proved to be a solution by achieving the highest levels of performance and sustainability criteria. MMC was defined as the combination of technologies that provide more products of better quality in less time (BURA, 2005).

Off-Site Construction is not a new concept to the UK (Arif, 2012): there is historical evidence of its use. The first known usage of OSC was in the construction of the Crystal Palace around 1851 (Gibb, 1999; Goulding and Arif, 2013). According to Smith (2011), Joseph Paxton regarded the Crystal Palace as being one of the earliest prefabricated buildings in the UK. Research by Goulding and Arif (2013) discussed the exporting of prefabricated homes from the UK to Australia in 1837. Off-Site Construction is therefore not a recent evolution. In the 20th century, world wars resulted in the mass construction of housing units. Manufacturing techniques were extensively used for this mass customisation of housing units (Goodier and Gibb, 2005; Pan et al., 2007; Arif and Egbu, 2010). Similarly, in the 1950s and 60s, the government implemented mass production to meet slum clearance and rehabilitation programmes. However, the attempt failed due to poor detailing and workmanship (Azman et al., 2010). In the 1990s, some research reports by the UK government emphasised the need to improve productivity in construction projects. Egan's report (1998), titled 'Rethinking Construction', examined the construction process and building methods in the construction industry. The report warned about under-achievement, low profitability and inadequate research and training in the industry. The same report also recommended the implementation of Standardisation and Preassembly (S&P) to improve the current situation of the construction industry. Again, in recent years the house-building industry has been challenged to build more new homes, while improving business efficiency to survive the recession. However, Pan (2010) criticised that the level of innovation in the house-building sector is still very low.

The acute need for housing was a major driver for the uptake of MMC in the UK, along with the extensive promotion by the government (Goodier and Gibb, 2007). Several initiatives by the government, such as the establishment of Constructing Excellence under the Office of the Deputy Prime Minister, the Housing Forum, and the UK government's housing agenda have encouraged the practice of MMC (Pan and Arif, 2011b; Pan et al., 2004; Kamar et al., 2010). Buildoffsite is working on the mission to 'bring about a step change in the exploitation of off-site applications in construction' (Buildoffsite, 2012). Buildoffsite has provided mutual communication and an exclusive focus on facilitating and promoting Off-Site Construction (Arif et al., 2012b). On the

other hand, innovation in construction materials such as timber framing systems, Large Panel Systems (LPS) and Structural Insulated Panels (SIP) have significantly pushed the development of prefabrication and pre-assembly techniques (Nawi et al., 2009; Mullens and Arif, 2006).

In order to examine the current utilization of OSC techniques and to identify the benefits and challenges associated with in; the government, a significant number of researchers and some professional and academic institutions have conducted a large amount of research. Pan and Arif (2011) discussed some of the recommendations by Egan, such as considering manufactured construction as the way forward for improving quality and efficiency in construction. The government of the UK also funded a research project entitled 'Promoting Off-Site Production Applications' (PROSPA) (Gibb, 2001). Various researchers have studied and critically analysed the Egan report. Loughborough University developed an Interactive Method for Measuring Pre-assembly and Standardisation benefits in construction (IMMPREST) through a software tool. This was an interactive tool to measure and evaluate the benefits from the adoption of the standardization techniques (Blismas et al., 2005).

Rapid commercial development created a great opportunity for the greater uptake of Off-Site Construction techniques (Azman et al., 2010). Currently, Off-Site Construction techniques have considerable commercial applications for businesses and a range of clients from hotels to retail outlets (Goulding et al., 2012; Mullens and Arif, 2006; Kamar et al., 2009). Prefabrication succeeded in achieving faster completion of commercial premises. The usage of prefabrication in McDonald's restaurants and Shell fuel stations was exemplary for such commercial buildings (Blismas, 2006). Examples like these have accelerated greater acceptance of OSC techniques in the commercial sector than in the residential and industrial sectors (Pan and Arif, 2011a).

Vernikos et al. (2012) documented that Off-Site Construction techniques have been applied in industrial construction as well as infrastructure projects. OSC methods are less labour intensive and produce greater quality, due to the closed-environment working conditions. The manufacturing process also enables repetition in production,

which is common in the products used in the construction of bridges and tunnels (Blismas, 2006).

Goodier and Gibb (2007) argued that the UK has remained behind similar economies in the application of OSC techniques and other forms of MMC. Nadim and Goulding (2010) reported that the market share of OSC in UK construction was below 6%. In 2004, Off-Site Construction techniques comprised only 2.1% of the construction work in the UK, including new building, refurbishment, repair and civil engineering work (Goodier and Gibb, 2004). The reluctance of clients to adopt innovative building techniques and materials was one of the major reasons for this minor share of OSC in the construction market (Pasquire and Gibb, 2002; Goodier and Gibb, 2007). Along with this, poor understanding of the benefits from OSC techniques challenged the spread of OSC. A study by Pasquire and Gibb (2002) criticised that the decision process for OSC techniques was unclear and complex.

The majority of researchers have considered OSC as a potential solution for the problems in the UK construction industry (Arif and Egbu, 2010; Blismas et. al., 2003; Goodier and Gibb, 2007; Vernikos et al., 2012). In the UK, the housing forum and Buildoffsite have religiously promoted offsite techniques to cope with the high demand for affordable housing and to improve overall performance in the construction industry (Arif and Egbu, 2010; Badir et al., 2002; Goulding et al., 2012). Nadim and Goulding (2010) proposed a strategy of providing adequate training and education to encourage people to accept, appreciate and embrace new ways of working and thinking.

2.10.2. United States of America

Off-site techniques or prefabrication exist in the United States historically (Lu and Liska, 2008). The use of off-site construction techniques originated with the development of the wooden frame house (Goodier and Gibb, 2007). Prefabricated construction was there in the beginning of Nineteenth century. For instance, the “Lustron home”, the “Sears Modern Homes” were constructed in a ready to assemble approach, which was also known as “kit house” (Goulding and Arif, 2013). The U.S. housing industry played key role in the extensive use of offsite techniques (Lu and Liska, 2008). The current housing market is driving home builders to integrate and to

invest in new technologies such as prefabrication (Yu et. al., 2008). Alongside, the growing demand for green / sustainable construction encouraged the usage of prefabrication in construction activities. Modular construction is widely accepted as an efficient construction method, particularly for residential building construction in North America (Li et. al., 2013). Some companies have also developed customised products for spacious and energy efficient residential construction (Holmes et. al., 2005). In construction of residential housing, healthcare, educational and office building sectors, off-site practices are extensively implemented in the U.S. However, this is more in housing and industrial projects when compared to that in commercial and infrastructure projects (Azman et al., 2012).

Modular Building Institute (MBI) is the major organisation dealing with off-site construction in the U.S. According to Eastman and Sacks (2008), off-site sectors have consistently shown higher growth in productivity than on-site sectors (Eastman and Sacks, 2008). Haas et. al., (2000) demonstrated that adoption of prefabrication and pre-assembly had significantly reduced the need for skilled workers onsite and also improved productivity of labour. However, Lu (2009) observed that the current level of adoption is limited in the construction industry despite significant advantages (Lu, 2009). According to Lu and Liska (2008), major barriers in the U.S. were the transportation restraints, limited design options and inability to make revisions during onsite execution. Further, other researchers identified additional factors such as misconceptions regarding modular construction, lack of awareness on the benefits and reluctance towards technological shift are hindering the adoption of offsite techniques in the construction industry in the USA [Lu and Liska (2008), Eastman and Sacks (2008) and Goulding, Rahimian, et al. (2012)].

2.10.3. Australia

The Australian construction industry also identified OSC as a key solution to improve the industry (Blismas et al., 2006). The construction industry has prioritised OSC in the vision document developed for the future (Blismas and Wakefield, 2009). High level of fragmentation, low levels of industrialisation, complex and inefficient supply chain, poor capitalisation, high reliance on sub contractors, declining skill base and lag in

training are hindrances for innovation in the construction industry in Australia (Azman et al., 2010; Hampson and Brandon, 2004). According to Blismas et al., (2010) the new manufacturing technologies and innovations have emerged in Australia through local and overseas connections. Hampson and Brandon (2004) reported that there will be more off-site production, more prefabrication and pre finished elements and products in Australia by the year 2020. Currently, the OSC sector covers a range of clients, from mass housing providers to the high-end custom built home suppliers (Goulding and Arif, 2013). Glasby (2008) identified that formwork systems, post-tensioned concrete floor systems and precast concrete utilisation are key drivers for a multi-rise building projects in Australia.

Cement, Concrete & Aggregates Australia (CCAA), reported that the Australian construction industry has experienced a period of under building (Glasby, 2008). The unfulfilled housing demand and sub-optimal supply-chain are challenges in the current industry in Australia.

Blismas et al. (2006) observed that, United States, Europe, United Kingdom and some Asian countries are at more advanced stage in developing prefabricated housing systems than Australia. In Australia, the much needed shift towards offsite practice was hindered by lack of suitable product and supply capability for the needs of current housing industry (Blismas et al., 2010).

2.10.4. China

Chinese construction sectors' main concern is about sustainability issues, like the rest of the world. In the literature, various studies have highlighted the scope of manufactured construction in different parts of China [Arif and Egbu (2010), Jaillon and Poon (2009) and Jaillon and Poon (2010)]. Hong (2007) stated that manufactured housing has greater potential in China. According to him "Housing industrialization has increasingly become a major alternative construction method in China". Researchers Jaillon and Poon (2008) stated that the environmental, economic and social benefits of using prefabrication were significant when compared to conventional construction methods in China. Arif et al (2010) investigated the housing needs and the manufacturing capabilities of China to explore the current practices of OSC in that country. This

research has mentioned China as a “Manufacturing Power House”. They documented about An exhibition titled “Prefab China 2013- Prefabrication and Modular Construction China 2013”, which was launched in China. This expo provided awareness and good networking among the manufacturers, service providers and potential clients (Prefabrication and Modular construction, 2013). Goulding and Arif (2013) discussed about this expo, as a significant initiative towards strengthening international and collaborative relationships in China.

Prefabrication is wide spread in private sector in recent years in Hong Kong [Jaillon and Poon (2008) and Chiang et al. (2006)]. The housing authority of Hong Kong intensified the adoption of prefabrication techniques in the mid-1980s (Chiang et al., 2006). The authority extensively used prefabricated components in the construction of public housing blocks for better workmanship, quality control and to maximize construction efficiency (Goulding & Arif, 2013). Research by Jaillon and Poon, (2008) discussed about the achievement of 52% waste reduction through implementation of OSC techniques. This also proved that OSC methods significantly reduce construction and demolition waste.

2.10.5. Malaysia

Off-Site or prefabricated construction is well known as the Industrialised Building System (IBS) in Malaysia (Badir et al., 2002; Hamid and Kamar, 2012). The Construction Industry Development Board (CIDB-Malaysia) defined the Industrialised Building System (IBS) as ‘a construction technique in which components are manufactured in a controlled environment (on or off-site), transported, positioned and assembled into a structure with minimal additional site work’ (CIDB, 2003). IBS is classified into Pre-cast Concrete Framing; Panel and Box Systems; Steel Formwork Systems; Steel Frame System; Prefabricated Timber Framing Systems and Block-Work System (Kamar et. al., 2011a). The IBS components, including, floors, walls, columns, beams and roofs have been extensively used in Malaysia in recent times. These components are often assembled and erected on site (Badir et al., 2002). The benefits of IBS have been observed in terms of cost and time certainty, attaining better construction quality and productivity, reducing risks related to occupational safety and health, and

solving issues regarding skilled workers and dependency on manual foreign labour (Alshawi et al., 2009; Hamid and Kamar, 2012).

The broader view of IBS was concerned with changing the conventional mindset, championing human capital development, developing better cooperation and trust, and promoting transparency and integrity (Kamar et al., 2011b). IBS was introduced and promoted to reduce foreign labour in the construction sector, and to improve the image of the construction industry, along with its performance (Kamar et al., 2009). IBS was proved to be a potential method to improve overall construction performance in Malaysia (Kamar et al., 2010).

The Malaysian construction industry has been under constant pressure to improve its performance (Kadir et al., 2006). The industry is also facing massive challenges in terms of sustainable development (Hamid and Kamar, 2012). In addition, acute housing need is another challenge. In Malaysia, under the seventh Malaysia Plan (1996–2000), the government drafted a housing programme to construct around 800,000 units of houses in both the public and private sectors (Badir et al., 2002). The conventional construction method was unable to meet the housing demand, due to the slow pace of construction and higher cost. Along with the urge towards greater productivity, another major reason was the domination of foreign labour in manual jobs in construction activities. The unskilled labour intake and 3-D (Dirty, Dangerous and Difficult) syndrome threatened the industry (Kamar et al., 2009 and Kamar et al., 2010). This also discouraged the local workforce and young graduates from entering the industry. In these circumstances, the Industrialised Building System (IBS) evolved as a way to bridge the gap between the demand and supply (Badir et al., 2002). According to Swee (1988, cited in Badir et al., 2002), the choice of IBS was influenced by the housing situation, land use, density, volume, environmental conditions, user needs, continuity of demand, and labour.

In Malaysia, IBS was introduced in the 1960s (Badir et al., 2002). Precast concrete beams and panelised systems were used in this early stage. The initial response to IBS was not as high as expected. The take-up rate of IBS in the Malaysian construction industry has been low, at a reported rate of only 10–15% of the overall volume of works

during 2003–2006 (Hamid et al., 2008; Nawi et al., 2011; Kamar et al., 2009). According to Azman (2010), the nature of the construction industry and misconceptions regarding IBS caused this lukewarm response towards IBS adoption. In addition to this, there were some failed projects that used IBS but resulted in time delays and cost overruns due to poor management. Accordingly, this resulted in the industry's reluctance to embrace IBS technology (Badir et al., 2002; Kamar et al., 2010). Then, IBS research was pioneered by the Housing Research Centre (Alshawi et al., 2009). The importance of IBS was highlighted under the Strategic Thrust 5 (Innovate through R&D) in the Construction Industry Master Plan 2006–2015 (CIMP 2006–2015). According to the Construction Master Plan (CMP) 2006-15, all government projects must be constructed only with IBS (Kamar et al., 2009). The CMP also announced incentives for construction organisations, such as the exemption from levy if the organisation used IBS.

The Malaysian government, along with the CIDB and other key players in the construction industry, highly prioritised and extensively promoted IBS in the construction sector. The government's initiatives included vigorous promotion and stringent instructions to use IBS for 70% of all construction activities. Along with the government, CIDB developed a roadmap titled the 'IBS Roadmap 2003–2010'. This provided a direction for IBS implementation and promotion activities. The roadmap guided the practitioners and policy makers on IBS-related issues (IBS Roadmap, 2003). This master plan scripted a '5M' strategy, namely Manpower, Materials-Components-Machines, Management-Process-Methods, Monetary and Marketing. The implementation of the roadmap was led by both the IBS steering and IBS technical committee. In parallel, the CIDB's IBS Centre monitored all the activities. This strategy resulted in the increased use of IBS in Malaysia: the number of IBS factories increased from 21 to 143 over seven years (Azman, 2010).

The CIDB also initiated a research collaboration with academic institutions to strengthen their R&D. Alshawi et al. (2009) explained the research collaboration between CIDB, the University of Salford and University Technology Mara (UiTM), aimed to develop the IBS framework, tools and model of implementation in the

Malaysian scenario. Alshawi et al., (2009) also documented the underpinning support offered by the CIDB to other industries.

Kamar et al. (2009) drew a comparison between the UK and Malaysia in the context of OSC. Their research also stressed the need for an organisation similar to Buildoffsite in Malaysia for two-way facilitation. Their research demonstrated the tendency of treating MMC or IBS as a threat to traditional construction methods.

2.10.6. Singapore

Singapore developed effective methods in off-site construction, through using precast reinforced concrete technology in the construction of multi-story buildings (Poh & Chen, 1998). Similar to Malaysia, the construction industry in Singapore highly depends on foreign labour. In Singapore a new legislation 'Buildability' has enforced all building projects to fulfill the minimum buildable score before the approval of building plans. Government made the 'buildability' assessment mandatory for all building developers under the Buildable Design Appraisal System (BDAS) (Lam & Wong, 2009). This BDAS was developed by the Building Construction Authority (BCA) in Singapore with an objective to determine the level of buildability of the system. The system computes a buildable score for each design. Therefore, the higher the buildable score, the greater the productivity of the design (Pheng & Chuan, 2001).

In detail, the computation of the buildable score consists of three main parts:

- Score for the structural system;
- Score for the wall system; and
- Score for other buildable design features.

Buildability was supported by the three principles of **S**tandardization, **S**implicity and **S**ingle integrated elements (3S) (Lam, 2002). Adoption of the 3S principles in design has a positive effect on buildability. Prefabrication has positively contributed to higher buildable scores. This encouraged the building and construction authority to promote just-in-time philosophy and offsite techniques in the construction approach (Pheng and Chuan, 2001). Empirical studies by Low and Abeyegoonasekera, (2001) and Low,

(2001) demonstrated a positive correlation between buildability, quality and productivity. Thus, the mandatory requirements for prefabrication were enforced indirectly through statutory compliance with “buildability” provisions in the building control system (Chiang et al., 2006).

Alongside, the Housing Development Board (HDB) of Singapore developed two basic approaches to address the shortage of skilled labour, to improve quality and to gain momentum in construction activities. In this strategy the board extensively promoted fully prefabricated reinforced concrete building system and semi-precast reinforced concrete building system. Gibb (2001) stated that the HDB, Singapore learnt lessons from the European experience and realised the importance of quality control of the panel connections and on-site workmanship. HDB also developed a volumetric bathroom unit based on a European system (Gann, 1996). The standardization of building components was the key to successful utilization of off-site construction technologies in Singapore.

2.11. Readiness and readiness models in construction

The section provides a discussion of readiness and some of the available readiness models in construction. These include Maturity Models, Benchmarking Models, Capability Maturity Models (CMMs), Innovation models, Readiness Models and Assessment Tools. The researcher studied some of these models from the existing literature to gain deeper understanding about the concept of readiness assessment and framework. The diverse knowledge obtained from the readiness assessment models in other technologies of construction will enable the researcher to design and customise the OSC readiness framework for construction organisations in India.

2.11.1. Readiness

In the literature, various definitions are available for the term ‘readiness’ in different contexts. Dada (2006) defined readiness in the context of Information and Communication Technologies (ICT) as, ‘The measure of the degree to which a country, nation or economy may be ready, willing or prepared to obtain benefits that arise from ICT’. Harvard University’s Centre for International Development (CID, 2000) defined

the term readiness as 'the degree to which a community is prepared to participate in the networked world – a world in which everyone, everywhere, has the potential to reap the benefits of connectivity to the network'. The majority of these definitions are discussed in the context of E-readiness. Generally, the term readiness is applied to measure the capability to adopt any new technology prior to its implementation.

2.11.2. Off-Site Construction readiness framework

For the current research context, Off-Site Construction readiness can be defined as 'a measure of the degree to which the organisation may be ready, prepared, or willing to obtain benefits which arise from the Off-Site Construction practices'. This was developed based on the E- Readiness definition by Lou et al., (2008). The ultimate aim of the OSC readiness framework is to investigate 'how ready is the organisation to adopt Off-Site Construction techniques in their current practice?' Thus, the Off-Site readiness framework investigates the extent to which any organisation is ready to adopt OSC technologies in various construction projects.

2.11.3. Review of selected models and frameworks in construction

In order to develop an offsite readiness framework, the researcher pursued an extensive review of the literature on maturity models in relevant areas. Some of the assessment models that have been extensively documented in the existing literature are listed as follows: MODEX; Neuromodex; the decision-making framework by Song et al. (2005); the Programme Management Maturity Model (PMMM); Standardised Process Improvement for Construction Enterprises (SPICE); Structured Process Improvement Framework for Construction Environments – Facilities Management (SPICEFM); Organisational Project Management Maturity Model (OPM3); Project Management Process Maturity Model (PM2); Portfolio, Programme and Project Management Maturity Model (P3M3); Verify End-user e-Readiness using a Diagnostic Tool (VERDICT); Interactive Method for Measuring Pre-assembly and Standardisation benefits in construction (IMMPREST); Readiness Assessment for Concurrent Engineering (RACE); the Process Model of Organisation (PMO); the Capability Maturity Model (CMM); and the Benchmarking and REadiness Assessment for

Concurrent Engineering in CONstruction (BEACON). Some of these models were adapted from other industries, such as manufacturing, software and information technology. However, scholars have drawn references from these existing models and developed a new model for the construction industry. Pan and Arif (2011) reviewed the theories of construction-manufacturing relations and developed a theoretical framework of construction-manufacturing relations. Similarly, Winch (2003) explored the relevance of the manufacturing models for the improvement of the performance of the construction process.

Various scholars (Bossink, 2004; Blayse and Manley, 2004; Koskela and Vrijhoef, 2001; Vernikos et al., 2011) have identified the factors influencing innovation in construction. Vernikos et al. (2011) explored the argument by Green (2011) that the fragmented nature of civil and infrastructure engineering projects does not encourage the straightforward implementation of management panacea from other industries. Further, Fernie et al. (2006) highlighted features such as the conservative attitude and adversarial culture of the construction industry. COMPREST (Cost Model for Pre-assembly and Standardization) investigated the standardization, pre-assembly design and construction processes within the Mechanical Services sector (Aldridge et al., 2001). This model was a developed based on a pilot study in an academic research university. According to Aldridge et al., (2001) the COMPREST study highlighted the poor availability of data on cost information and need for improved data collection procedures.

According to Keupp and Gassmann (2013), firms that innovate radically require moving away from current organizational routines, and replacing current practices by new knowledge bases. In the current research context, the construction organisations will be adopting Off-Site Construction as an innovation or unique technology in relation to the conventional construction practices. Hence, if the organisation achieves desirable maturity for adopting Off-Site Construction techniques, it would enjoy superior performance and possess competitive advantage.

Since OSC is an innovation in the construction context, and given the scenario of the Indian construction industry, it is important to manage this innovation. To improve

strategies of innovation management at organisational level, Pan (2010) developed an innovation management model with five key stages for managing innovation. These include the creation of ideas, the development of innovation, utilisation, review, and improvement or abandonment.

Readiness models have been used in various industries to assess the readiness and status of an organisation prior to introducing any new technology (Khalfan et al., 2001). In the development process of a readiness model for concurrent engineering in construction, Khalfan et al. (2001) explored various tools across the manufacturing and software industries. According to Khalfan et al., (2001), readiness models also identify the critical risks associated with implementation within the organisation, supply chain and other involved platforms.

Research by Khalfan et al. (2000) highlighted that conducting a readiness assessment of the organisation is one of the successful tools for implementing new technology in any organisation. It enables investigation of the extent to which the organisation is ready to adopt new technology or processes, and to identify the critical areas or risks involved in the implementation, within the organisation and its supply chain.

Various researchers (Ruikar, 2004; Khalfan et al., 2001; Chen et al., 2010) have identified that People, Processes and Technology are the three key aspects that need to be considered for the successful implementation of technologies (Ruikar, 2004; Khalfan et al., 2001; Chen et al., 2010).

Regarding prefabrication, the IMMPREST toolkit consisted of three tools, A, B, and C, which were developed to perform comparative evaluations of traditional and prefabricated construction. Tool ‘A’ was designed to reinforce the user-friendliness of the toolkit; tool ‘B’ was proposed to lead a strategic discussion on what is or isn’t appropriate for prefabrication while evaluating the project drivers and constraints; and tool ‘C’ was used to carry out detailed evaluations of six relevant factors (IMMPREST, 2007 cited in Graham et al., 2007). However, the IMMPREST toolkit provides limited information for projects at an early stage. Soetanto et al. (2005) developed a framework for the selection of a structural frame through the assessment of each criterion and the

likely performance of various structural frame options. Luo (2008) identified a list of generic prefabrication opportunities and tactics, and developed a decision-making tool using dynamic programming analysis (Chen et al., 2010).

Chen et al. (2010) developed a decision-making tool for construction method selection for concrete buildings. Meiling and Sandberg (2009) investigated a Swedish off-site house manufacturing company to reduce the feedback loops in off-site housing sales, design and production. An experience feedback model was proposed based on the literature review and case examples. The nature of some of the tools and models were explored in terms of the aim, developer, industry, survey method, usage and appropriateness for the construction sector. The researcher reviewed some of the readiness tools, maturity models found in the literature. The discussion can be found in the next sections.

2.11.3.1. RACE (Readiness Assessment for Concurrent Engineering)

This tool was developed at West Virginia University (United States) in the early 90's and was widely used in the software engineering, automotive and electronic industries. Khalfan et al., (2001) found that RACE can be modified to use in the construction and other industries. The RACE-model was conceptualised in two major components: **Process** and **Technology** (CERC Report, 1993 and Wognum et al., 1996).

2.11.3.2. PMO (Process Model of Organisation)

This model was developed to assess and analyse the **processes** and **technology** of an organisation. PMO can be used for analysing and designing an organisation, its processes, and technology. The purpose of this model is used to detect bottlenecks preventing the organisation to achieve its objectives (Wognum et al., 1996). Thus the PMO identifies key problem areas and the business drivers for any organisation.

2.11.3.3. PMO-RACE (A Combination of PMO & RACE)

PMO-RACE is the combination of two models (PMO and RACE) which was developed by the researchers at University of Twente and Eindhoven University of Technology

(Netherlands) in the mid 90's. According to de Graaf and Sol., (1994), the strengths of PMO and RACE were combined in this model. Hence, the characteristic features of PMO identify the key problem areas of the organisation and RACE determines the performance level of the product development process. This would improve the process cycles and deliver the best of both the worlds.

2.11.3.4. CMM (Capability Maturity Model)

According to Page et. al., (2004) Capability Maturity Model (CMMs) is fundamental mechanism used to provide guidance to organisations through defining processes. Capability is typically portrayed as a series of finite, increasing levels. Maturity can be defined as the over time "growth" of the capabilities. Model typically demonstrates an abstract representation of known or inferred properties, and can be used for further studies of similar characteristics. CMM was basically developed for software development and evaluation. This was designed and developed by the Software Engineering Institute at Carnegie Mellon University in order to manage the development of software for the US government (Aouad et al., 1998). The model has five levels of maturity naming ad-hoc, informal, systematic, integrated and continuous improvement. (Sun, Vidalakis, & Oza, 2009). This model can be used as readiness assessment model and, identified that the RACE model was developed on the concept of CMM (Khalfan et al., 2001).

2.11.3.5. SPICE (Standardised Process Improvement for Construction Enterprises)

This tool was developed at the University of Salford, United Kingdom. SPICE is in the form of a questionnaire, to document and assess the key construction processes within an organisation (SPICE Questionnaire, 1998). This tool is intended to evaluate the maturity of the processes of construction organisations. It was based on CMM and is presently a research prototype (Finnemore and Sarshar, 2000).

2.11.3.6. Project Management Process Maturity $(PM)^2$ Model

This 5-Level $(PM)^2$ Model was developed at the University of California, Berkeley in late nineties. The primary purpose of the 5-Level $(PM)^2$ Model is to use as a reference point or a yardstick for an organisation applying project management practices and processes. This 5-Level $(PM)^2$ Model further suggest applications to expertise and use of technology. The tool also helps in how to hire, motivate, and retain competent people (Kwak and Ibbs, 1997).

2.11.3.7. IMMPREST

Interactive **M**ethod for **M**easuring **Pre**-assembly and **St**andardisation was an interactive CD toolkit. The Toolkit comprises of three distinct tools, an Introduction and Information Tool (Tool A), an Interactive Benefit Indicator Tool (Tool B), and a Benefit Measurement Tool (Tool C). Each tool explains various levels of detail and specificity to the project and evaluates the elements. The first tool, introduces the subject of S&P at a general level. The second tool furnishes the user with a range of potential benefits and disadvantages for the given project objectives. The third tool provides a template for users to build-up a comprehensive benefit evaluation profile for any specific building element of a project (IMMPREST, 2007 cited in Graham et al., 2007).

2.11.3.8. BEACON Model

Benchmarking and Readiness Assessment for Concurrent Engineering in Construction (BEACON) Model was designed by Khalfan (2001) to assess Concurrent Engineering readiness in construction industry. The researcher used a questionnaire as one of the data collection tools to identify the key factors to be considered in the model. BEACON was divided into four sections to represent four aspects (Process, People, Project, and Technology) of the model. All the sections were divided into number of influencing factors to assess maturity level of the construction industry. For example, the first section had five critical process factors to examine process maturity level. Major difference between BEACON and previous discussed models is the inclusion of people

and project elements, which were missing in other models. Thus BEACON gave priority to people and project attributes along with process and technology. BEACON was developed from RACE model. Hence, similar to RACE, five levels (Ad-hoc, Repeatable, Characterised, Managed and optimising) have been adopted for every individual element. These levels further indicate the level of maturity of an organisation.

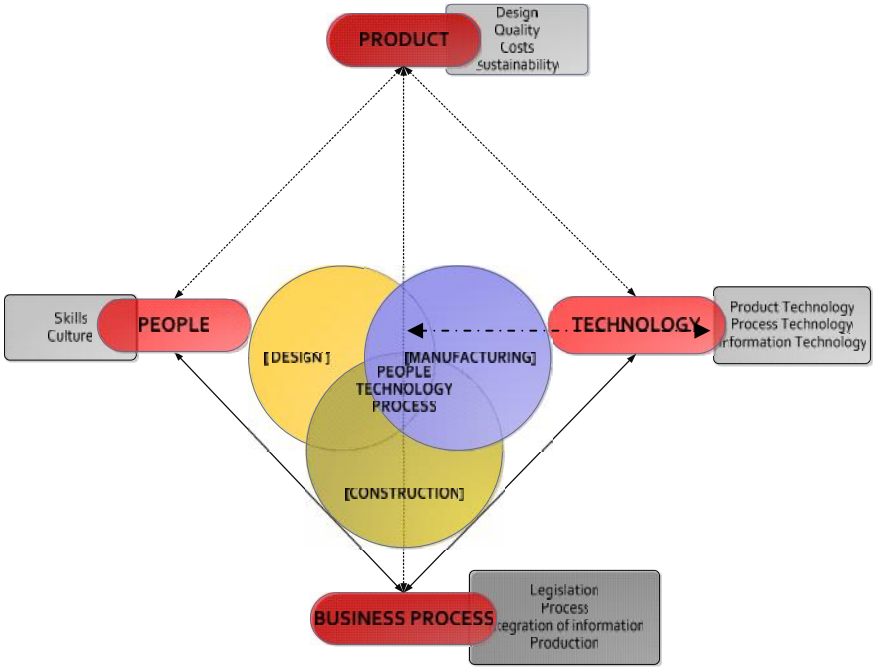


Figure 2.4 Merged model based on Goulding and Arif (2013) and Goulding et al. (2012) with core areas and patterns of concern in Off-Site construction

Tools/ Models	Aspects covered	Survey method	Appropriateness for use in Construction industry	Appropriateness for use in Off-Site Construction theme
RACE (Wognum et al., 1996)	- Process - Technology	Questionnaire and Interview	Appropriate for construction industry	Since this tool is appropriate for construction, the method can be taken as a reference while developing framework for OSC.
PMO Wognum et al., (1996)	- Organisational environment - Processes	Interviews, Description of past and current projects, formal procedures and quality hand book	Appropriate for construction industry	Since this tool is appropriate for construction, the method can be taken as a reference while developing framework for OSC.
(PM)2 Kwaak and Ibbs, 1997	- Planning to execute a projects - Definition of project activities -Cost estimates for the project - Project Management (PM) process - PM- related data collection and analysis - Utilisation of PM tools and techniques - Working as a team - Senior management support	Questionnaire	Appropriate for construction industry	Since this tool is appropriate for construction, the method can be taken as a reference while developing framework for OSC.
CMM Aouad et al., 1998	-Process -Information -Technology	Questionnaire and Interview	Developed for software industry. However, later the	Since this tool is appropriate for construction, the method

			appropriateness for construction industry was discussed by various researchers.	can be taken as a reference while developing framework for OSC.
SPICE University of Salford, UK, 1998	-Brief management -Project planning -Project tracking & Monitoring -Contract management -Quality Assurance -Project change management -Risk management -Organisation process focus -Organisation process definition -Training programme -Inter disciplinary co-ordination -Peer review -Technology management	Questionnaire	Developed for construction industry	Since this tool was developed for construction, the method can be taken as a reference while developing framework for OSC.
PMO-RACE Khalfan et al., 2000	Combination of PMO and RACE	Questionnaire and Interview	Appropriate for construction industry	Can be taken as reference for developing framework in the field of OSC.
BEACON Khalfan, 2001	-Process -People -Project -Technology	Questionnaire and Interview	Developed for construction industry	Can be taken as reference for developing framework in the field of OSC.
VERDICT Ruikar, 2004	-Process -People -Management -Technology		Developed for construction industry	Can be taken as reference for developing framework in the field of OSC.

IMMPREST IMMPREST, 2007 (cited in Graham et al., 2007)	-Introduction and Information tool (Tool A) -Interactive Benefit indicator tool (Tool B) -Benefit measurement tool (Tool C)	Questionnaire and Interview	Appropriate for construction industry	Developed to use in the Off-Site Construction

Table 2.8. Summary of key features of selected readiness tools

Readiness Assessment for Concurrent Engineering (RACE),

The Process Model of Organisation (PMO),

PMO-RACE (A Combination of PMO & RACE),

Capability Maturity Model (CMM),

SPICE (Standardised Process Improvement for Construction Enterprises),

Project Management Process Maturity Model (PM2),

Verify End-user e-Readiness using a Diagnostic Tool (VERDICT)

Interactive Method for Measu ring PRE-assembly and Standardisation benefit in construction (IMMPREST)

2.12. Summary of the review of models in construction

Before implementing any new technology, conducting a readiness assessment has been proved to be a successful approach. It helps to investigate the extent to which the organisation is ready to adopt the new technology or process, and to identify the critical risks involved in its implementation within the company. For instance, Concurrent Engineering (CE) readiness assessment has been successfully used for the planning of CE implementation in the construction industry and several other industry sectors, such as manufacturing and software engineering. The majority of the reviewed tools and models deal with improvements in the product development process and the implementation of technology in the development process. Some of the tools and models also address the organisational environment to support the development process. The BEACON model assessed four elements, named Process, People, Project and Technology. The VERDICT model assessed four elements, entitled Management, Processes, People and Technology. The maturity levels of the BEACON model were described as Ad-hoc, Repeatable, Characterized, Managed and Optimizing. The maturity levels of the Project Management and Process Maturity model were: Ad-hoc stage (level 1), Defined stage (level 2), Managed stage (level 3), Integrated stage (level 4), and Sustained stage (level 5).

In the reviewed OSC models and Off-Site Construction road maps, the majority of the researchers have considered investigating the issues related to Off-Site Construction in the areas of People, Technology and Process. For instance, Goulding and Arif (2013) and Goulding, et al., (2012) explored nine core areas, representing the three major dimensions of Off-Site Construction – Process, Technology and People – and their impact on Design, Manufacturing and Construction. Similarly, Nadim and Goulding (2011) documented the patterns of concern in typical OSC projects as the relation between Business Process, Technology, People and Product. According to Nadim and Goulding (2011), the Business Process, People, Technology and Product are interrelated in any OSC project. The researcher attempted to merge the two models discussed above, and created a new combined model illustrating the core areas of the Off-Site paradigm. Figure 2.4 above is an illustration of the combined model.

2.13. Chapter summary

This chapter presented an understanding on the concept of Off-Site Construction, different terms involved, types, and benefits of OSC, various factors influencing the uptake of OSC, including the critical success factors, the drivers and barriers towards successful adoption of OSC, and global trends in OSC. The researcher extracted factors from the existing literature to form base for further exploration in case of OSC in India. This list of factors will be examined in further chapters. It also explored the existing literature on various readiness models and assessment frameworks in the construction industry. The researcher focused on the elements, categories, and the criteria of these existing models in order to develop a deeper understanding on the concept of readiness assessment. This formed a basis for the conceptual readiness framework to assess OSC readiness of construction organisations in India.

The researcher found that OSC is gaining popularity to address the challenges of construction industry across the globe. These practices are significantly contributing to the sustainable environment. OSC is being treated as a “realistic” approach to improve quality, reduce time consumed on-site, and improve site safety. However, it is understood that the benefits are largely driven by the project –specific conditions and adopted combination of building systems / methods. Some of the researchers highlighted the lack of formal measurement procedures in terms of OSC. The review of literature found arguments on the decision and selection process of OSC based on subjective evidences.

The literature found that time, cost, quality, skill of the workforce, collaboration, working process, guidance, infrastructure, environmental performance, perception of the people and operational efficiency have significant impact on the implementation of OSC. The literature also discussed about the critical success factors in the context of OSC. The chapter identified a list of factors from the existing literature. The following table 2.9 presents the summary of factors along with the scope. This list will be further examined to assess the appropriateness of each factor in the context of Indian construction sector.

Table 2.9. Summary of key factors identified from the existing literature

S. No		Factor	Scope
1	TIME	Construction time (speed in construction)	Time for construction, time predictability, time to rectify defects and speed in construction
2	COST	Maintenance and operation costs / Disposal costs / Life cycle costs / Initial construction costs / Material costs / Labour cost	Cost for construction, cost predictability, cost of rectifying defects, cost in use
3		Speed of return on investment	Time taken for return of investment / break even.
4	PLANNING / PROCESS	Project planning and control / Project programme and scheduling	Arrangement of detail design, work delivery schedule and most cost effective way for installation and logistic. Improvement in site management effectiveness and optimum use of BIM
5		Production process / Lead-times / Process coordination	Adoption of manufacturing philosophy based on planned elimination of all waste and on continuous improvement of productivity (to name a few, Lean and Just – in – time approaches)
6		Early decision making to use offsite/ Early involvement of project team/ Design stage adoption	Key decisions on strategy, application, design, logistic and detail unit should be made as early as possible.
7		Technology (Machinery and equipment)	Availability and application of latest / suitable machinery and equipment.
8		Material consumption	Selection and consumption of materials and material auditing

9		Waste generation and disposal / Recyclable/renewable contents (elements)	Selection of material and Stock audit
10		Legislation / Understanding on building regulations	Building regulations, and fees etc.
11		Risk Management / Workers' health and safety	Risk assessment and mitigation to deal with decision making, mitigate design changes from the clients, risk of delayed payment and contractual issue
12		Site attributes/ Site disruption, Transportation and lifting	Current status of site. Difficulties experienced in previous projects.
13		Local conditions / Transportation and infrastructure/ Traffic congestion / Road network	Transportation and logistics. Such as road network for transporting huge containers if needed.
14	PROCUREMENT	Procurement System (or) strategy / Partnering / Integration of supply chains/ Management supply chain	Improvement in procurement strategy which includes identification of suppliers, manufacturers and sub-contractors not only with the low cost but with right capability, competency and capacity. Planning and management of all supply chain activities including procurement, conversion, logistic and coordination. Attention to detail management of all stages, enabling correct and timely information to be available
15	PEOPLE (SKILLS + WORKSPACE)	Working collaboration / Communication and information flow	High level of cooperation between the main contractor, sub-contractors, suppliers (to solve the problem at site particularly which related to complex interfacing between systems) to ensure efficient processes sequence on site.

16		Communication flow	Accurate and timely information is essential to coordinate processes and deal with critical scheduling (Successful implementation of BIM)
17		Information and Communication Technology (ICT)	Development, implementation, support and management of computer based information system to improve tendering, planning, monitoring, distribution, logistic, supply chain, information flow, project management and cost comparison. Implementation of BIM.
18		Training/ Experience and competent workforce	Retrained and re-skilled labour workforce to fit offsite skill sets. Broader and comprehensive training program must be taken on board to cater vast demand in these specialised skills. Include professional education and hands on training. Experienced workforce capable of high level of planning organizing and controlling function with respect to production, coordination and installation of components
19		Governance / Policy and strategy match / Project control guidelines / Integrated environmental and economic program / Business planning and process/ Continues improvement / Principles and values / Vision and corporate motivation	Clear vision and strong intention from management to convince the decision makers, customers, clients and own organisational to use offsite and to ensure the right motivation and commitment from the whole construction team. Strategic business approach and corporate positioning. Establishing clear business need and build strategic plan around it.
20		Working conditions / Inclusive environment	The workforce / staff of the organisations must feel comfortable and respected. Environment must encourage workforce towards positive contribution to the goals of the project / organisation.

21		Aesthetic options | Design / Design standard and project function	Arrangement of detail design and standardisation in designs
22		Standardisation	Standard building products, standard form of contract, standard details, design or specifications and standard processes, procedures or techniques. Simplify things and further reduce overall cost and schedule
23		Constructability	Ease in construction / erection
24		Usage efficiency	Products / design being user friends
25		Adaptability and flexibility	Having capacity to be modified for new use / purpose
26		Integration of building services	Integrating all the building services (plumbing, electricity, HVAC and Fire safety etc.) at the time of design.
27	DESIGN	Durability	Durability of the project / products used
28		Defects and damages	The way defects / damages are addressed

The literature also found that initial efforts, promotion, follow up action on policies implementation, and knowledge exchange among countries will significantly improve the adoption of OSC techniques in the construction industry. For instance, the influence of the Singapore C21 report on Malaysian construction industry was highlighted in the literature. Similarly, many researchers from Malaysia have studied about the global practices, and considered the working practices in the UK before proposing road map for implementation of IBS in Malaysia. Several researchers discussed about the role of government and other research and academic organisations in accelerating the adoption of OSC. To name a few, Buildoffsite (UK), Modular Building Institute (USA), the Construction Industry Development Board (CIDB) of Malaysia have played influential role in promoting OSC methods.

This chapter also discussed about readiness, readiness assessments and various tools available in the existing literature. According to Khalfan et. al., (2000) readiness assessment of the organisation provides the status of the organisation that is to what extent it is ready to adopt new technology or processes. Further, it also identifies the

critical areas in the implementation of technology within the organisation. The nature of some of the tools and models were explored in terms of the aim, industry, survey method, usage and appropriateness for the construction sector, and OSC context. Majority of the previous studies have dealt with improvement in the product development process and the implementation of technology in the development process. Some of the tools have addressed the organisational environment to support the development process. In the reviewed Off-Site Construction road maps, majority of the researchers have presented the findings in the areas of People, Technology and Process.

This chapter contributes to the research objectives by documenting the offsite construction paradigm, influencing factors and existing practices in other countries through literature review. It also presents the list of factors to be examined in order to identify the drivers and barriers towards the adoption of OSC in India. Further, it provides understanding on the readiness assessment tools. The next chapter (chapter 3) will introduce and discuss the research methodology used in this research.

Chapter 3 | Research design and Methodology

This chapter presents the research philosophy, research design, and data collection techniques that are being considered for this study. This chapter also discusses the philosophical position, epistemological and ontological assumptions of this research. The researcher has adopted a mixed method research approach since it was the most appropriate approach to answer the research question, and to meet the objectives of the current research.

3.1. Introduction

Various researchers have defined research in different contexts. Creswell (2003) defined it as a method of data collection and analysis while Leedy and Ormrod (2005) referred to it as a systematic process of collecting, analysing and interpreting information in order to increase the understanding of the phenomenon about the research area. According to Collis and Hussey, (2003), research is a scientific and systematic method of finding a solution to a problem. They considered research as an overall approach to the design process right from the theoretical underpinning to the data collection and data analysis.

Several researchers have demonstrated the importance of understanding and interpreting data, events, assumptions and results in the field of study. The subsequent discussion in this chapter is structured on a framework adopted from the 'Research Onion' introduced by Saunders, Saunders, Lewis, and Thornhill (2009). The developed framework is comprised of research philosophy, approach, methodologies, techniques and procedures applied in this research effort, as illustrated in Figure 3-1.

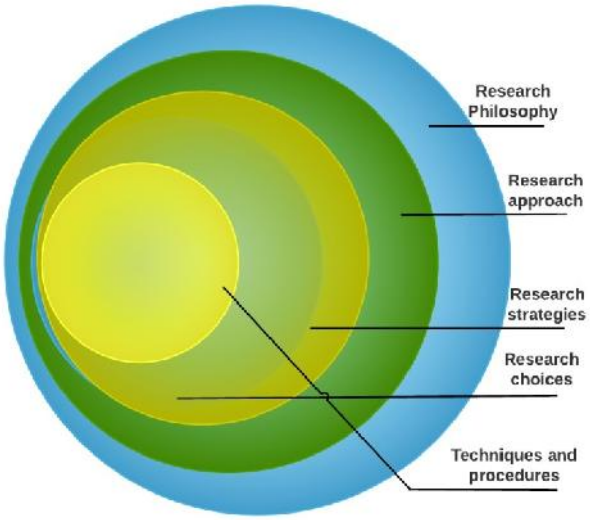


Figure 3.1. Frame work for the discussion [developed on the basis of the research onion by Saunders et al. (2009)].

3.2. Research philosophy

In general, research philosphy demonstrates the established empirical stand and underpinning philosphy in the research process. Saunders et al (2009) defined philosophy in the research context. According to them, research philosophy relates to the development and nature of knowledge. Ruona (2005) belives that philosophy includes thinking about questions, making interpretations, exploring ideas, presenting the potential arguments and experimenting with the impact of various concepts. Easterby – Smith et al. (2008) highlighted the importance of research philosophy in general for any research, and according to them understanding the research philosophy and extensive work on research methodology enables the researcher to identify the appropriate research design and approach for any research.

The researcher's view (assumption) of the world (research area) is channeled through the selected philosophy. The research philosophy describes researchers' perceptions with important assumptions. These assumptions support the research strategy and methods to be adapted in order to progress the research (Saunders, et. al., 2009). Research Philosophies point to the appropriate methods of inquiry and also direct researchers towards appropriate methods of conducting proper research (Neuman & Kreuger, 2003).

Research philosophy deals with the overall epistemological, ontological and axiological issues of research and research activities (Pathirage et al, 2008). According to Creswell (2003), philosophically researchers ask "What is knowledge and the nature of reality?" (ontology) and "How do we know about it?" (epistemology). Each philosophy is constructed, observed and measured using a different social reality (method of understanding the world) (Neuman & Kreuger, 2003). Easterby-Smith, Thorpe, and Jackson (2008) explained the difference between ontology and epistemology thusly: "Ontology is the philosphical assumption about the nature of reality while epistemology refers to the set of assumptions about the best ways to inquire into the nature of the world". The researchers' view of ontology effects their epistemological stand which, in turn, effects their view of human nature and the choice of methodology (Holden & Lynch, 2004). Also, the choice of quantitative or qualitative research strategy is guided by the epistemological and ontological considerations of the researcher (Bryman, 2004).

3.2.1. Ontology and the Ontological position of current research

Ontology describes the nature of the reality (Saunders et al. 2009). Ontological assumption is concerned with what is believed to constitute a social reality (Grix, 2001). According to Grix (2001), the individuals' ontological position is their answer to the question 'what is the nature of social reality to be investigated?' Ontology portrays whether reality really exists, i.e. objective reality, or whether it is created in the researcher's mind, i.e. subjective reality. The two major ontological positions are objectivism and subjectivism (Saunders et al. 2009; Bryman and Bell, 2007). These were described as a continuum's polar opposites, with varying philosophical positions aligned between them (Holden & Lynch, 2004).

In literature, there was extensive debate on the subjective and objective positions in regards to research. Also, objectivism and subjectivism were differently labelled in the literature. Table 3.1; adopted from Hussey and Hussey (1997) and Holden and Lynch (2004), provides an idea on different names used in the literature. Objectivism depicts the way social entities exist independent of social actors (Saunder et al. 2009). Saunders et al., (2009) explained the subjectivist view as the social phenomena created from the

perceptions and consequent actions of social actors. According to Huizing (2007), the assumptions from an objectivist perception provide people with law-like, rational knowledge which enables successful functioning in the external world. In subjectivism, understanding of knowledge, truth and meaning can be achieved through an ongoing interaction with the physical environment and with other people.

Table 3.1. Alternative names of philosophical paradigms used in literature

Objectivist	**Subjectivist**
Quantitative	Qualitative
Positivist	Phenomenological
Scientific	Humanistic
Experimentalist	Interpretivist
Traditionalist	
Functionalist	

Source: Hussey and Hussey (1997) and Holden and Lynch (2004)

Current research aims to develop an OSC readiness framework for Indian construction organisations. In order to achieve this, the researcher attempts to understand the reality through the evidences and experiences of the current OSC practitioners in Indian construction; thus, the researcher deals with the objective data. In parallel, this research also investigates the key factors which encourage or hinder the adoption of OSC practices in India. For this, the researcher attempts to observe the current practices as well as the perceptions and consequent actions of other social factors, such as awareness and people's perception. Hence, the ontological stand of current research lies more towards the subjectivism shown in Figure 3.2.

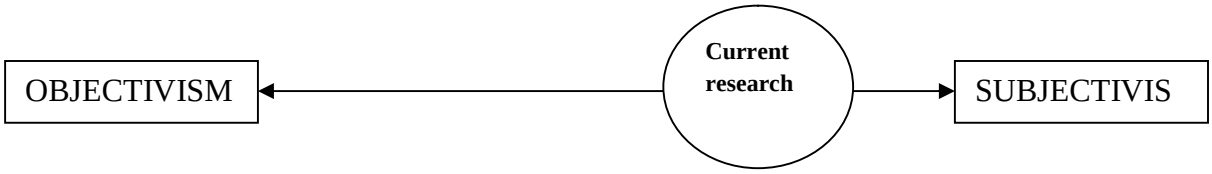


Figure 3.2. The *Ontological* position of current research

3.2.2. Epistemology and the Epistemological position of current research

The epistemological perception deals with the question of what could be considered as acceptable knowledge in the field of study (Bryman & Bell, 2007). It considers the nature and criteria of knowledge, its possibility, scope and general basis. These questions are also concerned about 'how we know' and the knowledge acquisition methods (Bryman, 2004, Bryman & Bell, 2007 and Dainty et al., 2007). According to Easterby-Smith et al. (2008), epistemology is regarded as a general set of assumptions about the best ways of enquiry about research. The two major epistemological assumptions are positivism and social constructivism or interpretivism (Easterby-Smith et al., 2008; Saunders et al., 2009).

Positivists believe that the world is actually concrete and external; therefore their exploration can only be based on the observed and captured facts through direct data or information. Positivists consider that reality is stable and can be observed and described from an objective viewpoint (Easterby-Smith et al., 2008). A majority of the positivists use quantitative research methods for data collection and analysis (Mackenzie & Knipe, 2006).

On the opposite side, interpretivists believe that the world is not objective and exterior, considering that it is based on a social construction in which people create and interact (Saunders et al., 2009). In this position researchers give importance to their beliefs and value while exploring a research problem (Easterby-Smith et al., 2008). The interpretivist/social constructivist believes that reality can be understood fully only through the subjective interpretation in reality. They argue that the real world is determined by people rather than by objective and external observable factors (Easterby-Smith et al., 2008). Therefore, in the interpretivist perception, both the way that people feel and behave are as important as the way they are observed/recorded (Creswell, 2013).

In the context of current research, researchers explore the state of OSC in India, for which the majority of the contribution is from the practitioners in the field of construction, India. The researcher significantly relies on the study of observations and evidence that is measurable. Hence the position lies towards positivist. However,

another research objective, i.e. identifying the factors, conceptualising and testing the OSC readiness framework, demands an extensive literature review, study of expert views and observation of events and processes of organisations. Thus, it requires interpretation of people's perception, social behaviour and other external factors. Hence, the researcher also takes the position of being interpretivist. However, the epistemological stance of the researcher is more towards interpretivism as shown in Figure 3.3 below.

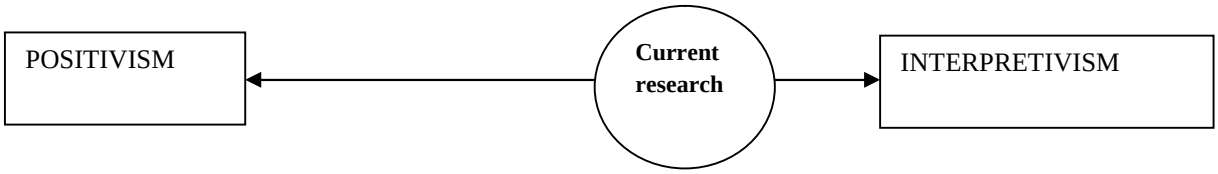


Figure 3.3. The *Epistemological* position of current research

In some cases, it is difficult to understand the real situation from several perspectives, and current research is one such scenario. OSC is relatively new paradigm in India. A detailed discussion on the research area is provided in the Introduction (Chapter 1). It is difficult to distinguish or take a completely positivist or social constructivist position. Easterby-Smith et al. (2008) discussed similar cases. According to them, in complex situations, in order to understand the nature of real world the researcher may decide to adopt a combined research approach during the research design stage.

3.2.3. Pragmatism

As a philosophical approach, pragmatism is not committed to any single type of philosophy or reality (Creswell, 2003). The pragmatic paradigm places the research problem at the heart of the research process and uses any available, suitable approaches to understand the problem Creswell (2013). Pragmatists link the choice of approach directly to the purpose and nature of the research questions (Saunders et al. (2009) and Creswell (2013). According to Bryman (2007), the pragmatic researchers are not limited to epistemological and ontological positions. Instead they focus on ways of combining qualitative and quantitative methodologies in the overall research process. This paradigm provides the fundamental philosophical framework for mixed-methods research (Teddlie and Tashakkori, 2003).

In the pragmatism approach, the researcher can take both the positivist and interpretivist positions (Morgan, 2007). According to Pansiri (2005), the concept of pragmatism provides a useful middle philosophical ground for combining different types of research approach into a single workable solution to address the practical research problems effectively. Morgan (2007) stated that, pragmatism offers an effective alternative through emphasising on the abductive– inter subjective –transferable aspects of the research. According to Ardalan (2009), in pragmatic research both paradigms "share common fundamental assumptions about the nature of social science and the nature of society".

3.3. Research approach

Research approach is underpinned and driven by the understanding and perspective of the researcher. Creswell (2013) highlighted the importance of the research approach in developing an effective strategy and increasing the validity of research. The most commonly used research approaches are inductive and deductive (Saunders et al., 2009). In simple terms, an inductive approach involves building a theory and a deductive approach involves testing a theory. In the deductive approach, the researcher develops a theory and hypothesis and then designs a research strategy to test it. Alternative theories may evolve through the deductive approach (Saunders et al., 2009). The sequential stages involved in deductive research are as shown in Figure 3.4 below.

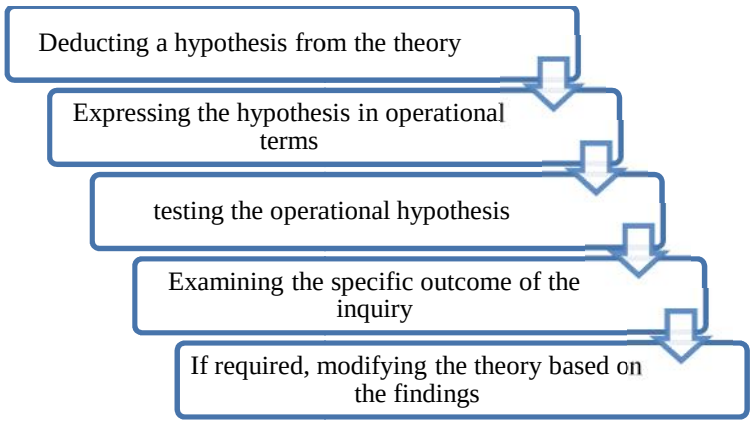


Figure 3.4 Sequential stages in the deductive approach. Adopted from Robson (2002), discussed in Saunders et al. (2009).

In the inductive approach, the researcher first collects data and develops a theory based on the results of the data analysis. The inductive approach provides better understanding about the nature of the problem (Saunders et al., 2009). This is evident in several types of qualitative data analyses (Thomas, 2006). In this approach, researchers make observations about a set of relevant data and then attempt to discover patterns that may point to more general theories. The stages involved in the inductive research approach are illustrated in Figure 3.5 below.

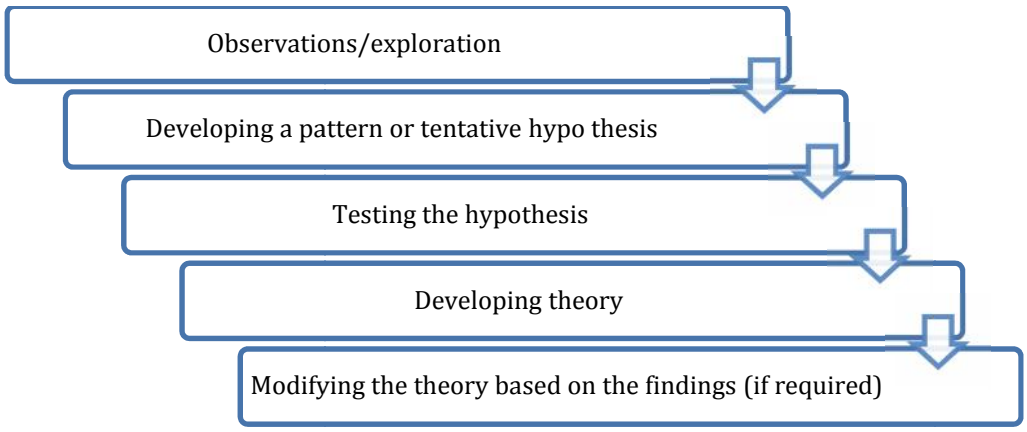


Figure 3.5 Sequential stages in the inductive approach. Adopted from Saunders et al. (2009).

Also, the major differences between the inductive and deductive approaches are articulated in Table 3.2. According to Thomas (2003), the primary purpose of the inductive approach is to allow research findings to emerge from the frequent, as well as significant themes inherent in raw data, without the restraints imposed by structured methodologies.

Table 3.2. Major differences between the deductive and inductive approaches to research

Deductive approach emphasises on	**Inductive approach emphasises on**
Scientific principles	Gaining an understanding of the meanings human attach to events
Moving from theory to data	A close understanding of the research context
The need to explain casual relationships between variables	A more flexible structure to permit changes of research emphasis as the

	research progresses
The collection of quantitative data	The collection of qualitative data
The application of controls to ensure validity of data	A realisation that the researcher is part of the research process
The operationalisation of concepts to ensure clarity of definition	Less concern with the need to generalise
A highly structured approach	
Researcher independence of what is being researched	

Source: Saunders et al. (2009). Pg 127.

In general, many researchers adopt both inductive and deductive approaches (Hyde, 2000). The balanced use of them leads to flexibility in the research and balanced perspectives (Hyde, 2000; Saunders et al., 2009).

Current research was pursued with a deductive approach. The research involved moving from theory to data, i.e. developing an OSC readiness framework and the testing of applicability of concepts through validating the developed framework. The approach of current research is as shown in Figure 3.6. This involved research activities such as exploring and documenting existing literature, identifying influencing factors, understanding and documenting the current state of OSC in India through data collection and analysis, conceptualising an OSC readiness framework and testing and validating the framework.

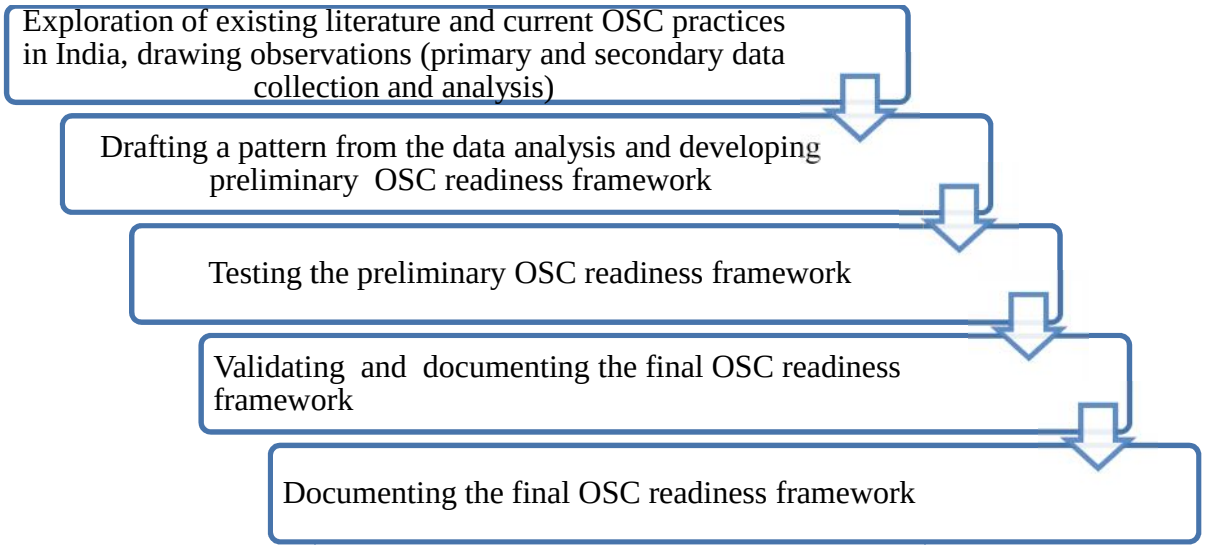


Figure 3.6 Illustration of the research approach for current study

3.4. Research Methodology and methods

The research utilises several functional methods to answer the research questions. The important factors in choosing a research methodology are the aim of the research, epistemological concerns and other previous work on similar topics/areas (Buchanan & Bryman, 2007). The research methodology focuses on the process or steps and the kind of research tools and procedures needed to obtain the required data within a single study (Mouton, 2011). The research methodology is important since it determines the research methods to be used in order to answer the research questions (Saunders et al., 2009). The overall methodology of this research is discussed in detail in the coming sections.

In literature, various authors used research methodology and research methods interchangeably. However there are conflicts in the use of these terms. According to Grbich (1999), methodology is the various ways of gathering data that are driven by the selected philosophical orientations whereas method is a way of gathering data. Creswell (2013) agrees and expresses that methods are the specific techniques of data collection and analysis. Methodology is the overall approach to the proposed research linked to the paradigm or theoretical framework to be used (Mackenzie and Knipe, 2006).

Research methodologies are broadly classified into quantitative, qualitative and mixed methods (Saunders et al., 2009). This classification is based on the data characteristics and collection methods. According to Creswell (2013), no particular method has an advantage over the other.

3.4.1. Qualitative research method

The qualitative research method helps to address questions that cannot be answered by way of quantification (Ospina, 2004). With it, researchers focus on capturing the existing experiences and perceptions of the participants involved in the process under investigation (Johnson, Onwuegbuzie, & Turner, 2007). According to Gable (1994), the qualitative research method is good for emerging research fields such as the adoptability and readiness in terms of new technologies (current research area). Exploratory qualitative research helps researchers in acquiring information about research issues when there is very little information available or known (Liamputtong, 2006). Creswell (2013) observed that qualitative research as a process of understanding based on distinct

methodological traditions of enquiry that explore a social or human problem. This method enables interpretation of the subjective experiences of individuals and their perspectives (Grix, 2001). According to Burke (2007), the qualitative method is the most suitable way of exploring issues based on social phenomenon. However, it adopts a relatively open-ended data collection approach with indefinite limits to the research process (Bryman, 2006). Traditionally the qualitative research method is associated with case studies, phenomenology and the grounded theory approach. These tools are often applied in research within a built environment (Amaratunga, Baldry, Sarshar, & Newton, 2002).

Several researchers have discussed the advantages of the qualitative research method. Ospina (2004) , Saunders et al. (2009), Harrison and Reilly (2011) and Petty, Thomson, and Stew (2012) summarised the benefits of using qualitative research methods as below:

- Provides in-depth knowledge and understanding through the exploration of experiences from participants in their natural setting;
- Produces more detailed explanations of human phenomenon as well as in-depth analysis of complex human and cultural dynamics, where the same cannot be captured with a numerical measurement approach;
- Explores a phenomenon that has not been studied before;
- Develops understanding of any phenomenon that is difficult to approach quantitatively.

On the other hand, the qualitative research method was also criticised by significant authors. Greater dependence on interviews as a principal methodology in qualitative research is commonly documented as a drawback (Amaratunga et al., 2002; Brannen, 1992; Punch, 2013). Castro, Kellison, Boyd, and Kopak (2010) pointed out the inability of providing generalised results due to the limited size of samples.

In the area of off-site construction and related research topics, many researchers adopted qualitative research methodology. Some of them include C. Goodier & Gibb (2007), Lu, (2009), Nadim & Goulding (2010) and Pan et al. (2004).

3.4.2. Quantitative research method

Quantitative research involves a systematic scientific investigation of quantitative properties and phenomena and their relationships (Amaratunga et al., 2002; Saunders et al., 2009). It is objective in nature (Creswell, 2013). Similarly, quantitative research significantly adopts a deductive approach to data collection and analysis (Saunders et al., 2009). The entire process uses the deductive form of logic where theories and hypothesis are tested with a cause-and-effect format (Saunders et al., 2009). Traditionally this research method involves the measurement of numbers from large data gathered from various people across a large geographical area (Creswell, 2013). The quantitative method generates statistics through the use of large scale surveys, utilising tools such as questionnaires and/or structured interviews, symbolic models and physical experimentation (Dawson, 2009 and Naoum, 2007).

Quantitative research methods are also widely criticised by various researchers. A majority of the criticisms are in regard to the questionnaire, the data collection tool. The over reliance on questionnaires as the main data collection instrument hinders the interaction and the exploration of social issues in their natural settings (Buchanan & Bryman, 2007). The closed–ended questions and restrictive nature of such instruments limits the exploration of human factors in details, and this affects the reliability of the findings (Fellows & Liu, 2009). Quantitative research demands a good understanding of the research area in advance in order to judge and justify the variables (Saunders et al., 2009). A summary of the key features of qualitative and quantitative research methods is presented in Table 3.3.

In the current research area, a significant number of researchers adopted the quantitative researcher methodology. Badir et al. (2002), Ern and Kasim (2012), Kamar et al. (2009), Taherkhani, Saleh, Nekooie, and Mansur (2012) and Pan (2006) are some of the researchers in this category.

Table 3.3. Important features, strengths and weaknesses of qualitative and quantitative research methods.

Method	Features	Strengths	Weaknesses
Qualitative research	• Uses inductive approach • Involves theory building • Employs subjective approach • Open and flexible approach • Researcher is close to the respondents • Employs theoretical sampling • Uses explicative data analysis • Low level of measurement	• Able to understand people's meaning • Able to develop the theory • Able to generate data in natural setting • Open data collection approach	• Difficult to control the pace, progress and end-point of research process • Can be time consuming • Data interpretation can be difficult • Limited (small) sample
Quantitative research	• Uses deductive approach • Involves theory testing • Employs objective approach • Closed and planned approach • Researcher is distant from respondents • Employs random sampling • Uses deductive data analysis • High level of measurement	• Able to test the hypothesis • Able to collect large sample • Findings can be generalised	• Used methods tend to be inflexible and artificial in nature • Unable to capture human phenomena effectively

Source: Sarantakos (2012) and Amaratunga et al. (2002).

3.4.3. Mixed research method

A mixed research method is the type of research in which researcher or a team of researchers combine elements of qualitative and quantitative research approaches (view points, data collection, techniques, analysis, inferences) for better understanding and

corroboration (Johnson et al., 2007). According to A Tashakkori (2003), mixed method research allows the researcher to answer quantitative and qualitative questions simultaneously. This method combines elements of qualitative and quantitative view points, data collection and analysis techniques in a single study (Creswell, 2013; Hanson, Creswell, Clark, Petska, & Creswell, 2005). Mixed method research aims to draw from the strengths and minimise the weakness of both the methods in single research study. Adoption of this research method enables the researcher to minimise and reduce the over-dependence on statistical data to explain a social occurrence and experiences that are subjective in nature (Jogulu & Pansiri, 2011). According to Creswell (2013), mixed method research provides more comprehensive evidence for studying a research problem than either using quantitative or qualitative research alone. Mixed methods research is increasingly being accepted as the third major research method and has become popular in various disciplines (Hanson et al., 2005; Johnson et al., 2007). The principle of this method enables the researcher to collect data from multiple sources in order to investigate the hard and soft issues associated with human and organisational areas without compromising the scientific rigor of the findings (Masadeh, 2012). The key strengths and weaknesses of applying mixed method research methodology are presented in Table 3.4.

Table 3.4 Strengths and weaknesses of applying mixed methods

Strengths	**Weaknesses**
• It provides a strong evidence for conclusion • Increases the ability to generalise the results • Produces more complete knowledge that is necessary to inform theory and practice • Answers a broader range of research questions • Uses the strength of an additional method to overcome the weakness in another method	• More expensive and time consuming • Researchers need to fully understand how to use multiple methods and approaches • Difficult when used in a single study • Can be difficult for a single researcher especially when the two approaches are used concurrently

Source: (Amaratunga et al., 2002; Castro et al., 2010; Creswell & Garrett, 2008) (Harrison & Reilly, 2011; Abbas Tashakkori & Teddlie, 2003).

Though the mixed methods approach is well received by the researchers, some believe that this method is incompatible. Sale, Lohfeld, and Brazil (2002) argue that the qualitative and quantitative methodologies are drawn from different epistemological assumptions and have different research cultures that work against the mixing of research methodologies. On the contrary, Buchanan and Bryman (2007) and Saunders et al. (2009) stated that the use of mixed methods through the combination of different data sets provides different views, perceptions and experiences. Though arguments continue on this method, built environment researchers have often adopted the mixed method research approach, as highlighted by Amaratunga et al. (2002). According to them, this method has a wide number of advantages, particularly in a built environment. Current research uses the mixed methods research methodology.

3.5. Data collection tools

The collection of data for any research is a "communication process" between the researcher and the respondents (Fellows & Liu, 2009). This data collection process enables the researcher to identify and simultaneously deal with essential themes and social processes (Saunders et al., 2009). Various tools are available for data collection. Some of them include focus group discussion, questionnaires, interviews (structured, semi-structured and unstructured), record reviews and observations (Saunders et al., 2009). The choice of appropriate data collection and analysis method for a study is determined by the research question and research approach. Hence, the researcher must select an appropriate data collection tool in order to achieve the aim. The research paradigm, primary research methods and the suitable data collection tools are illustrated in Table 3.5.

Table 3.5. Research paradigm, primary methods and data collection tools

Paradigm	Primary methods	Data collection tools
Positivist	Quantitative methods	• Experiments • Quasi – experiments • Tests • Scales

Interpretivist	Qualitative methods	• Interviews • Observations • Document reviews • Visual data analysis
Pragmatic	Qualitative and / or quantitative methods	• Techniques from both positivist and interpretivist paradigms (example- interviews, observations, experiments and testing etc.)

Source: Mackenzie and Knipe (2006)

A summary of the selected data collection tools in this research is presented in table 3.6. The table indicates the techniques used for gathering data to achieve each research objective. A discussion on the used data collection tools (literature review, questionnaire, interviews and case study) follows in the next section.

Table 3.6. Research objectives with corresponding data collection tools

Research objectives	**Data collection techniques**			
	Literature review	Questionnaires	Interviews	Case study
To understand and document the Off-Site Construction paradigm and influencing factors through literature review;	√			
To investigate the drivers and barriers towards the adoption of Off-Site Construction in India and document existing strategies in other countries;	√	√	√	
To conceptualise an offsite readiness framework to assess the maturity level and preparedness of the construction organisations to adopt Off-Site Construction practices in India;	√	√	√	
To test and validate proposed framework in construction organisations, India;			√	√

To demonstrate findings, conclusion and recommendations for future research	√	√	√	√

3.6. Population and sample

It is important to identify the population and define the sample size for data collection. The population is the total number of members of the group that the researcher is interested in studying, and a sample is a subset of the population that is usually chosen to serve as a representation of the views of the population (Saunders et al., 2009). Sampling is the process of identifying and selecting "units if the target population which are to be included" in a particular study (Sarantakos, 1998), and it is necessary since it is rarely possible to examine the entire population due to time, money and other resources (Burke, 2007). A quantitative research sample needs to be representative of the population in order to produce a result of theoretical and practical value (Fellows & Liu, 2009). The sampling technique presents the most suitable mechanism through which the needed information can be obtained. According to Bryman (2006), the adoption of sampling is vital to any research project.

Researchers must be careful when choosing the appropriate sample size during the research design stage so that the selected sample size truly reflects the entire population (Naoum, 2007). The exercise on sampling sizes should consider the nature of the research questions, time and resource availability, as well as the characteristics of the population (Black, 1999; Saunders et al., 2009). The size of the sample should be guided by the research objective, research questions and the research design (Johnson et al., 2007; Kotrlik & Higgins, 2001). In general, researchers choose small samples in qualitative research and large samples in quantitative research (Saunders et al., 2009). A brief summary on the key differences between qualitative and quantitative sampling is provided in Table 3.7.

Table 3.7. A summary of the key differences between qualitative and quantitative sampling

Qualitative sampling	Quantitative sampling
• Relatively small sample • Less expensive • Less time consuming • Flexible parameters • Occurs during data collection • Often based on saturation • Not representative • Respondents are treated as persons • Sample size is statistically not determined • Selection is influenced by the researcher	• Relatively large sampling • High cost consuming • Time consuming • Fixed parameters • Occurs before data collection • Based on probability theory • Representative • Respondents are treated as units • Sample size is determined statistically • No bias in selection

3.6.1. Sampling Techniques

In literature, two major types of sampling techniques are extensively discussed. These techniques are probability or representative sampling and non-probability sampling (Saunders et al., 2009). These are briefly discussed in the next section.

In a probability sample, all the members of the population are known even before a sample is drawn. Each member has a known chance of being selected as a sample (Bryman 2008). Probability sampling techniques adopt well structured and stringent procedures for the identification and selection of samples from the target populations (Sarantakos, 1998; Saunders et al., 2009). These techniques are useful in cases where a high degree of reliability and generalisation of the findings are required (Sarantakos, 1998). Non-probability sampling techniques are mainly adopted by the qualitative researchers due to their flexible nature (Saunders et al., 2009).

3.7. Questionnaire design and strategy

This research adopts electronic methods in its questionnaire design, distribution and subsequent data collection processes. Currently the use of a web-based or internet questionnaires are becoming popular due to their ease in terms of administration.

According to Denscombe (2009), the use of online questionnaires in social research provides grounds for confidence that online questionnaires might possibly produce lower item non-response rates than their traditional paper counterpart. The use of a web-based online survey offers advantages such as cost efficiency, quick response time, faster delivery, ability to track, design options, better addressing of sensitive issues and having the same strengths as postal surveys or a paper version (Wright, 2005).

3.8. Chapter Summary

This chapter has discussed about the research methodology, strategy and research methods for data collections used to achieve the aim and objectives set out for this research. The researcher adopted the ontological position of "subjectivism" as the current research attempted to observe the current practices, perceptions, and consequent actions of other social factors such as awareness and people's perception. The research required identification of factors, conceptualising and testing the OSC readiness framework. These research activities involved study of expert views and observation of events and processes of organisations. This has led the research to take interpretivism in terms of epistemological position. The research was conducted with a deductive approach method. The research was pursued in the "moving from theory to data" pattern. The chapter presented the sampling techniques, advantages, disadvantages, strengths and weaknesses of the qualitative research, quantitative research and mixed method research. The exploratory nature of the research has encouraged the researcher to adopt the mixed method approach. The researcher gathered data from both qualitative and quantitative tools. The data was collected through questionnaire survey, semi-structured interviews and case studies. The next chapters will present the results of the data analysis of the quantitative questionnaire survey and qualitative semi structured interviews of the research. The next chapter will also present the overview of the questionnaire, piloting questionnaire, and selected sample and distribution of questionnaire in detail.

Chapter 4 | Development of Off-Site Construction readiness framework through data analysis

This chapter presents the findings from the questionnaire survey used in this research. The researcher has analysed data and identified the critical factors acting in the adoption of Off-Site Construction in India. The author of this thesis has documented the descriptive data results, the findings of the factor analysis and the results from other statistical analysis in this chapter.

4.1. Questionnaire survey of current research

The survey questionnaire is planned as a research tool in the first stage of this research. It aims to understand the present status of Off-Site Construction in India. This phase attempts to answer the research questions:

1. *Are the Indian construction organisations aware of Off-Site Construction (OSC) methods and the associated benefits? What is the current status of OSC in India?*

2. *What factors drive and hinder construction organisations in pursuing OSC practices in India?*

The primary objective of this questionnaire is to identify the nature and extent of current OSC practices in Indian construction organisations. It has focused on the views of Architectural, Engineering and Construction (AEC) professionals in regard to OSC, current practices and the delivery of Off-Site Construction projects in India.

The second objective of this survey is to identify the key factors influencing the adoption of OSC in Indian construction organisations.

4.1.1. Overview of the questionnaire

The results from the literature review presented in Chapter Two are directed to the content of the current questionnaire survey. The questionnaire consisted of three sections; section one enquires general information about the respondents - which is optional; while section two and three provide questions on construction experience and

Off-Site Construction experience, respectively. Section One consists of three questions providing background information about respondents. In section two, question one asks the respondent to identify their organisational nature in terms of principal business activity. Question two seeks to classify respondent's nature of job in the organisation through indicating their current job title. Questions three and four seek information regarding the respondents' experience in the construction industry and the major sub-sectors in which their organisation is involved. For instance, the sub-sectors include hospital, leisure, educational and hotels etc. Section three seeks information on their current experience in OSC projects; that is, their views, opinions and observations on OSC projects and trends in India. In this section, question one asks the respondent's experience in OSC area, while question two deals with the number of completed OSC projects in their career to date. Question three seeks the respondent's view on the current use of OSC in India.

The subsequent questions in this section deals with the organisation's strategy on implementing OSC, the nature of sub sectors in which OSC techniques were implemented, the types of OSC in current usage, as well as rating the advantages of using OSC, rating the influencing factors and distinguishing whether the factor discourages or encourages the uptake of OSC in Indian construction market. This section also poses a question on the current availability of information on OSC in India since OSC is relatively new in India. The final question offered respondents an opportunity to provide additional comments. Here, the respondents were provided with open-ended answering box (comments box) to add their views or comments on the variables of questions in section three. This enables the researcher to capture any additional factor from the respondents' experience/knowledge which has not been highlighted in the literature review.

4.1.2. Piloting questionnaire

After the design of the questionnaire, it was initially evaluated through piloting prior to its final distribution. The initial draft version of the questionnaire was sent for comments to eight (8) respondents in both academic and industry. The response rate for the pilot survey was one hundred percent. The respondents indicated that it took

between twenty (20) to twenty five (25) minutes to complete the survey. The respondents observed that two questions were creating confusion and leading to similar information. Moreover, there was a technical error which prevented the respondent from selecting the impact (discourage or encourage) of influencing factors. These issues were addressed in the revised questionnaire. The feedback and comments obtained from the pilot survey thus helped in refining the overall design and structure of the questionnaire.

4.1.3. Selected sample and questionnaire distribution

The research is centred on developing a readiness framework for utilising OSC techniques in construction organisations in India. Therefore, organisations applying OSC are more familiar with both the philosophy and the principles involved. Hence, the best samples in making this inquiry are those of construction organisations who have adopted OSC techniques in their projects. However, being that the total number of Indian construction organisations implementing Off-Site Construction is unknown, a purposive non-probability sampling technique was adopted (Bryman and Bell, 2007).

Currently, there are no organisations similar to Buildoffsite in the UK, which are dedicated to working on promoting OSC in India. However, in the literature, many researchers have highlighted the sustainable feature of the OSC practices. Based on this, the researcher approached the Indian Green Building Council (IGBC), which promotes and supports sustainable practices in the built environment of India. A list of organisations applying OSC was prepared from the green practitioner book provided by the IGBC. Another list of professionals (Engineers) was obtained from the Institution of Engineers, India (IEI).

The Institution of Engineers is the national organisation for engineers in India. IEI has over 0.5 million members from 15 engineering disciplines in 99 centres/chapters in India and overseas (IEI, 2016). A third list of the professionals (Architects) was prepared from the information provided by the Council of Architecture, India (COA) and the Indian Institute of Architects (IIA). The COA and the IIA are the national bodies of architects in India. These organisations maintain the register of practicing architects in India. The researcher, being an architect, is a registered member in the

COA. This has enabled the researcher to get the information that is accessible to all the registered members.

However, it is important to note that not all the practicing engineers and architects use OSC practices in their projects. In order to reach the OSC practicing organisations and to make up a larger sample and increase participation, the snowball approach (Bryman 2008; Denscombe 2010) was also adopted. For current research, the researcher applied this technique through requesting participants to refer other potential professionals / organisations engaged in OSC projects in India.

The researcher invited 410 professionals to participate in the questionnaire survey. A web-based questionnaire with a link to the survey was sent to OSC practicing professionals. In the end, 218 participated in this questionnaire survey. Thus, the response rate of the questionnaire survey was 53.17. Out of the 218 responses received, 14 responses were incomplete. Hence, the researcher considered the 204 responses (49.76% - invited 410 participants) for the data analysis.

4.1.4. Rationale of survey questionnaire

Several previous studies have provided an overview of the use and adoption of OSC and influencing factors towards the adoption of OSC in other practicing countries. Significant research studies have been conducted through the questionnaire survey, or a combination of questionnaire and other qualitative data methods. For instance, Goulding and Arif (2013), Nadim and Goulding (2010), Goodier and Gibb (2007) and Pan et al. (2004) on the United Kingdom and Europe; Blismas and Wakefield (2009) on Australia; Eastman & Sacks, 2008; Haas & Fangerlund, 2002 on USA; Kamar et al. (2009), Kamar et al. (2010) and Majid et al. (2011) on Malaysia; Lam (2002) and Poh and Chen (1998) on Singapore; Jia et al. (2011) and Zhang and Skitmore (2012) on China have all executed a questionnaire survey approach. Similarly, this researcher has adopted questionnaire survey in order to investigate the status of OSC in India. The results of this study will contribute to the research and practice in construction industry through providing an understanding of the current usage of OSC and challenges associated with the adoption in India.

4.2. Descriptive Statistical Analysis

4.2.1. Respondent's profession

The first question of the questionnaire concerned the general information about the participant, i.e. their current profession. The majority of the participants are Engineers (55 in number), while architects are the second highest number (52). The cumulative of architects and engineers among the data set is 52.5%; this means that 107 respondents belong to A& E domains of construction industry. The survey only attracted 11 policy makers, who represent 5.4% of the total respondents. The results are portrayed in the table below. A distribution chart is also provided in the figure below.

Table 4.1 Respondents' profession

	Profession	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	52	25.5	25.5	25.5
	Engineer	55	27.0	27.0	52.5
	Developer	32	15.7	15.7	68.1
	Manufacturer / supplier	16	7.8	7.8	76.0
	Policy maker	11	5.4	5.4	81.4
	Contractor	38	18.6	18.6	100.0
	Total	204	100.0	100.0	

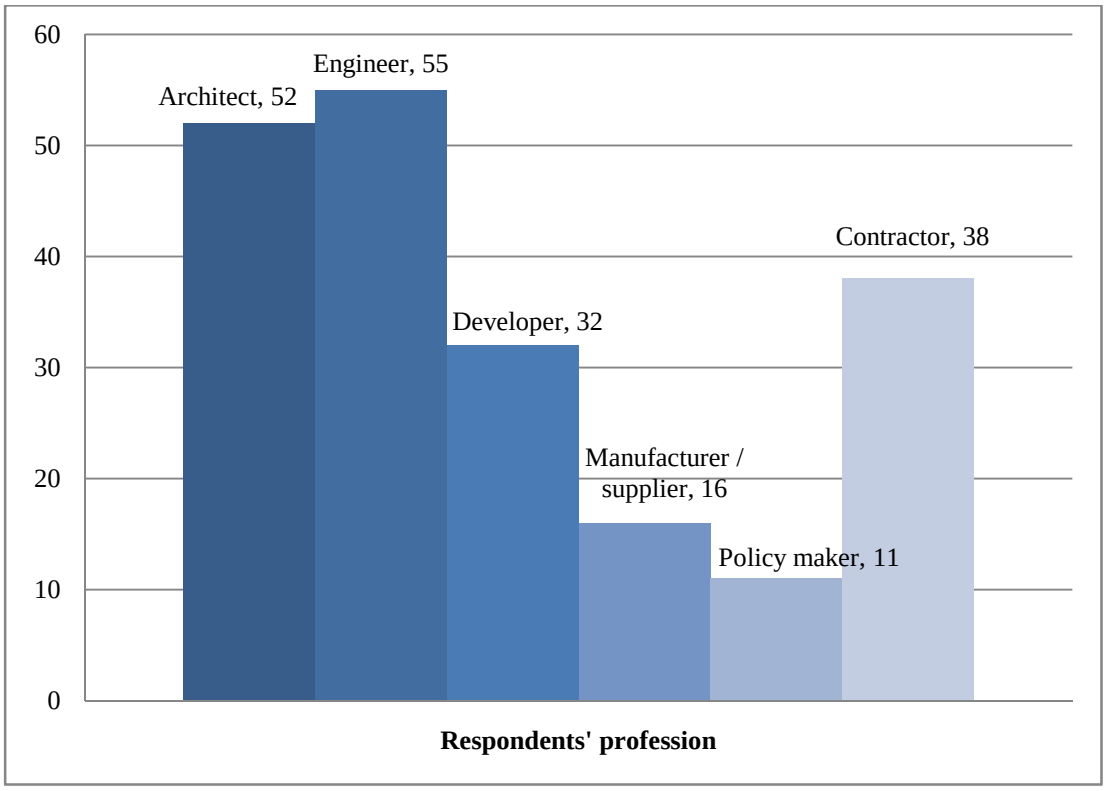


Figure 4.1. Descriptive statistics of respondents' profession

4.2.2. Current position in the organisation

The questionnaire survey was predominantly answered by the middle level managers in various organisations. In terms of numbers, 109 middle level staff (53.4%) have participated in this survey. In the next place, 64 senior managers recorded their views in this survey. The figure below provides further details of the responses. The survey also attracted 18 directors of various organisations. The table below demonstrates the distribution of participants in numbers.

Table 4.2. Current position in the organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Director	18	8.8	8.8	8.8
	Senior position / Senior Manager	64	31.4	31.4	40.2
	Middle level	109	53.4	53.4	93.6
	Technical staff	13	6.4	6.4	100.0
	Total	204	100.0	100.0	

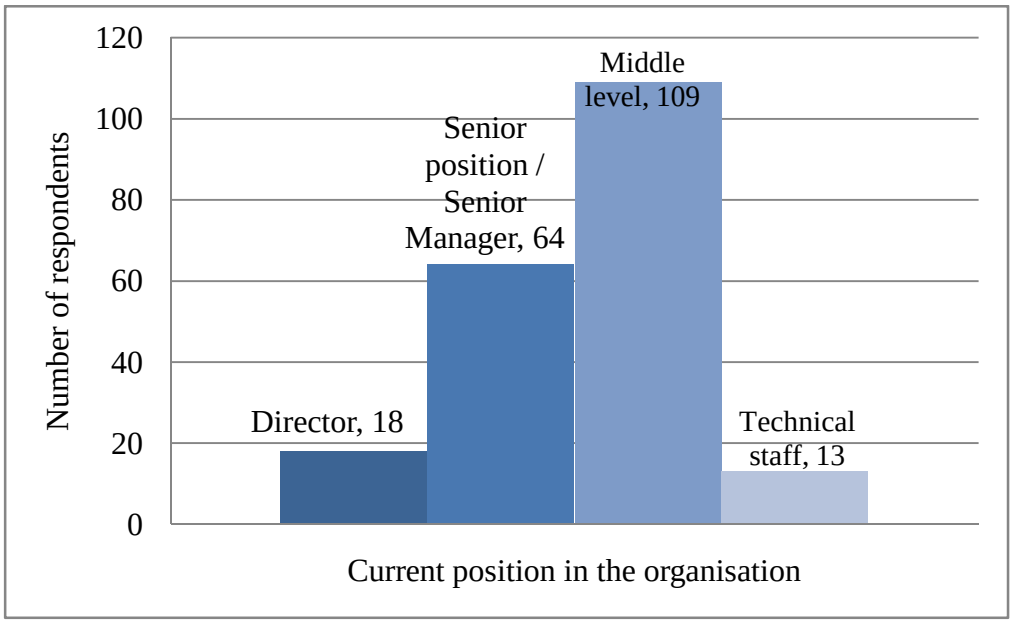


Figure 4.2. Descriptive statistics of respondents' job level in the organisation

4.2.3. Experience in the construction industry

Among the respondents, 91 members had experience of less than 5 years in the construction industry. Hence, 44.6% of the sample have less than 5 years of experience. Secondly, 56 members have 5-10 years of experience. Furthermore, 40 members have 10-15 years of experience while only 17 members have more than 15 years of experience in the construction industry. The table and figure below show the experience of respondents in the field of construction.

Table 4.3 Total years of work experience in the construction industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<5 years	91	44.6	44.6	44.6
	5 to 10 years	56	27.5	27.5	72.1
	10 to 15 years	40	19.6	19.6	91.6
	>15 years	17	8.3	8.3	100.0
	Total	204	100.0	100.0	

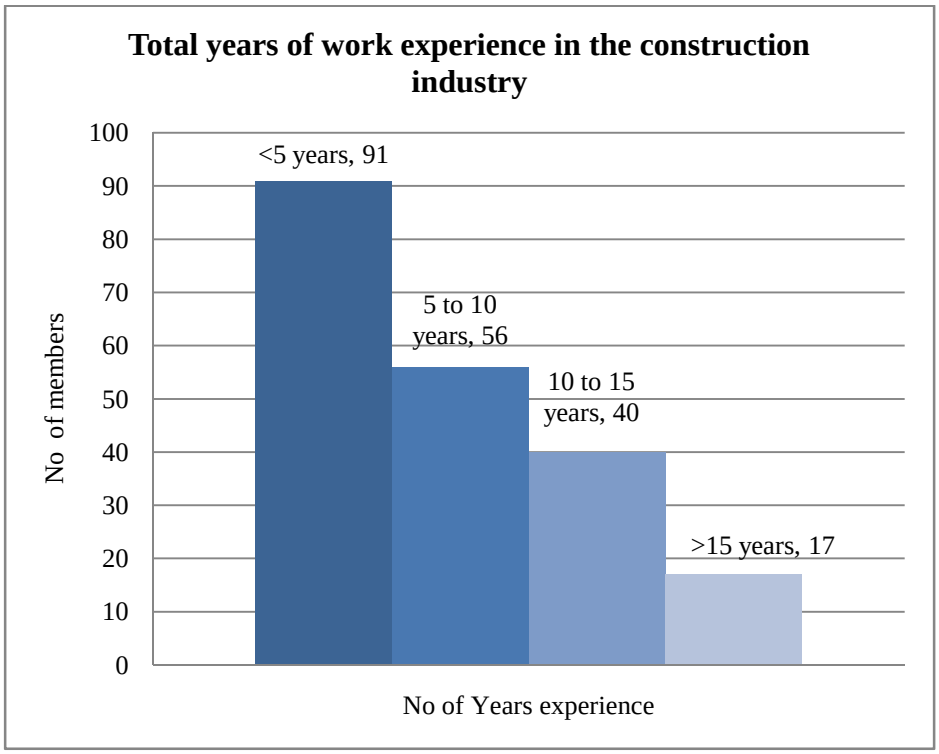


Figure 4.3. Descriptive statistics of respondents' experience in the construction industry

4.2.4. Experience in OSC projects

Out of the 204 respondents, 105 respondents have less than five years of experience in the OSC projects. This is 51% of the total population. In the next place, 61 participants have experience of more than five, but less than ten years of experience. Only 16 participants have more than fifteen years of experience in the OSC projects. The table and figure below illustrate the findings in this area.

Table 4.4. Experience in OSC projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<5 years	105	51.4	51.4	51.4
	5 to 10 years	61	29.9	29.9	81.3
	10 to 15 years	22	10.8	10.8	92.1
	>15 years	16	7.9	7.9	100.0
	Total	204	100.0	100.0	

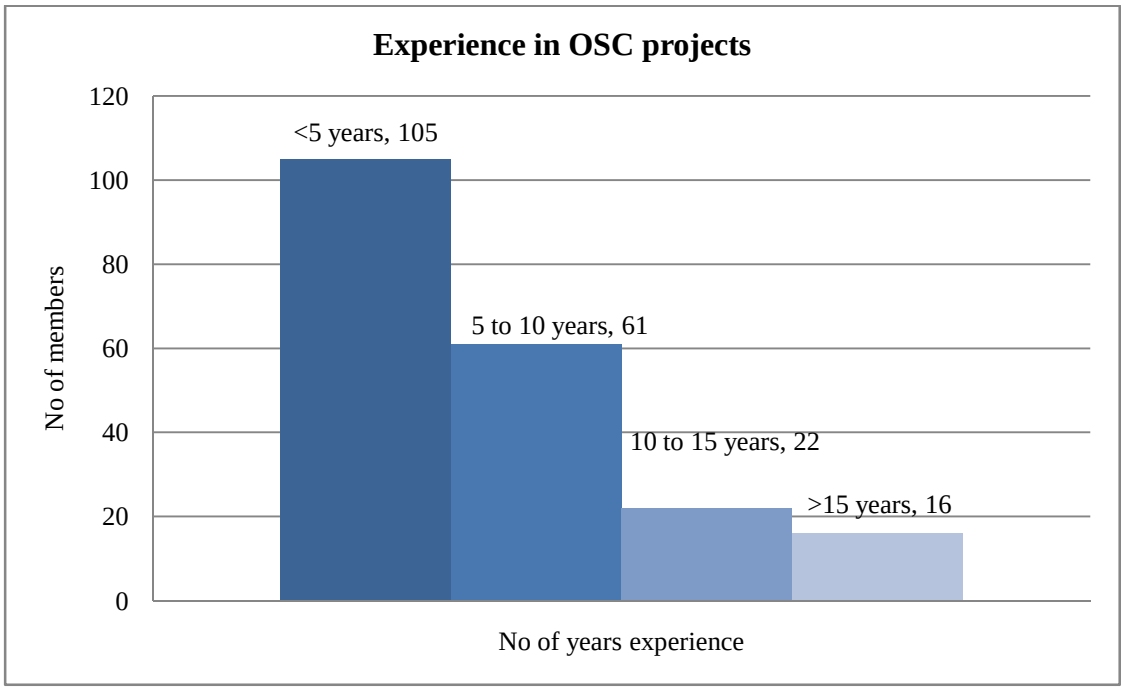


Figure 4.4. Descriptive statistics of respondents' experience in the Off-Site Construction projects

4.2.5. Number of completed Off-Site Construction projects

Amongst the 204 respondents, 53 have yet to finish any Off-Site Construction project. However, 104 participants have completed between one to ten projects. Further, 11 respondents have finished 11-20 projects. The table and figure below shows the number of respondents and the projects completed respectively.

Table 4.5. Number of completed OSC projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	53	26.0	26.0	26.0
	1-10 projects	140	68.6	68.6	94.6
	11-20 projects	11	5.4	5.4	100.0
	Total	204	100.0	100.0	

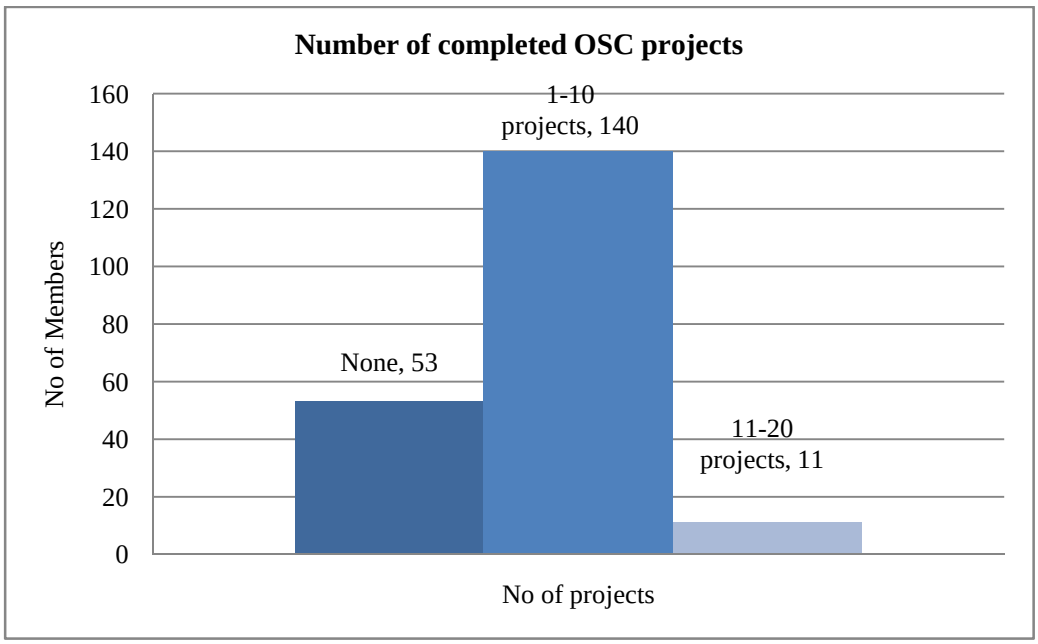


Figure 4.5. Descriptive statistics of number of completed Off-Site Construction projects by respondents

4.2.6. Current usage of Off-Site Construction techniques in India

Forty three participants (43) were of the opinion that the current usage of OSC techniques in India are unsuccessful. However, the majority of the participants, i.e. 84 participants, were neutral about the current position of OSC practices in India. At the second best, 56 participants remarked that current practices are good in the country. While thirteen (13) participants noticed the OSC practices are very unsuccessful, eight

participants recognised that the current practice of OSC in India are excellent. The table below is a detail demonstration of the obtained data.

Table 4.6. View on current usage of OSC techniques in India

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very unsuccessful	13	6.4	6.4	6.4
	Unsuccessful	43	21.1	21.1	27.5
	Neutral	84	41.2	41.2	68.6
	Good	56	27.5	27.5	96.1
	Excellent	8	3.9	3.9	100.0
	Total	204	100.0	100.0	

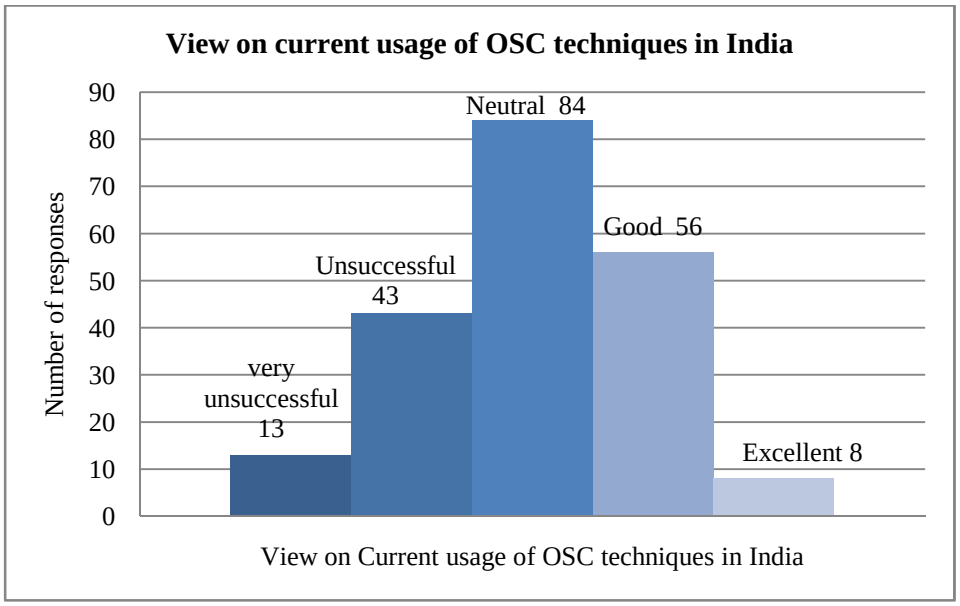


Figure 4.6. View on current usage of OSC techniques in India

4.2.7. Organisation's plan in terms of increasing offsite application in future projects

Out of 204 participants, 88(43%) stated that their organisations are interested in increasing the OSC application in the future. Furthermore, 80 participants highlighted that their organisations would maintain the same trend of applying OSC to their future projects. However, 36 participants mentioend their organisations' plan to decrease OSC application. The figure and table below illustrate the responses of the participants to this question.

Table 4.7. Organisations' plans in terms of increasing offsite application in future projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Increase	88	43.1	43.1	43.1
	Decrease	36	17.6	17.6	60.7
	Maintain same	80	39.2	39.2	100.0
	Total	204	100.0	100.0	

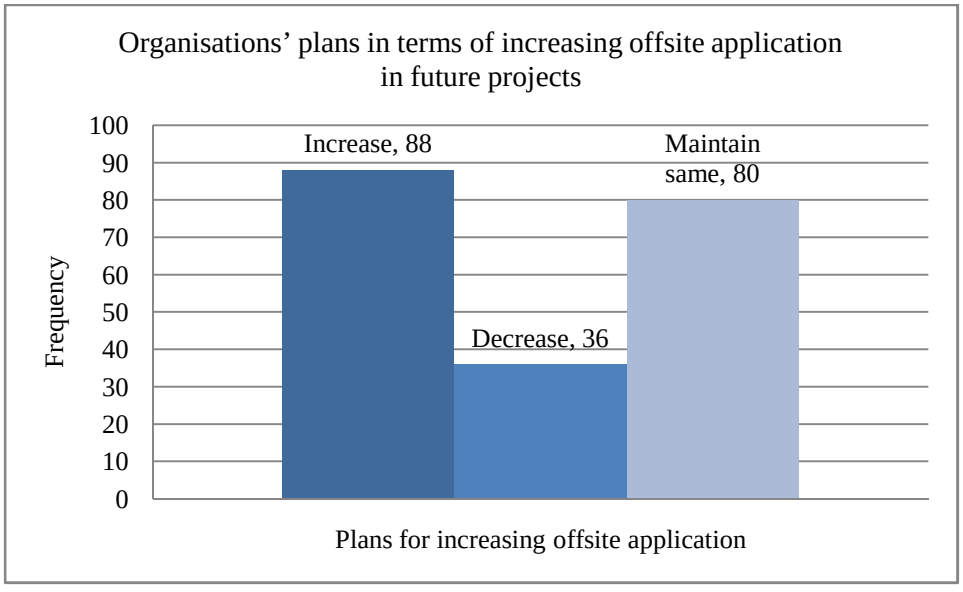


Figure 4.7. Organisations' plans in terms of increasing offsite application in future projects

4.2.8. Methods involved in the current Off-Site Construction projects

The majority of the organisations are currently practicing the method of “Precast some components and cast the main structure on site”. Thus, 69.1% of the population have highlighted that they have used this method. Only 7 participants noted that they have used or using the method of “Precast the whole building and lift onsite”. In the additional comments, the participant provided that this method was adopted for a private group housing project in one of the metropolitan cities in India. The table and figure below demonstrates the distribution of usage in the current data.

Table 4.8. Methods involved in the current Off-Site Construction projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Precast some components + Cast main structure on site	141	69.1	69.1	69.1
	Precast all components + Assemble on site	56	27.5	27.5	96.6
	Precast the whole house / building + Fix on site	7	3.4	3.4	100.0
	Total	204	100.0	100.0	

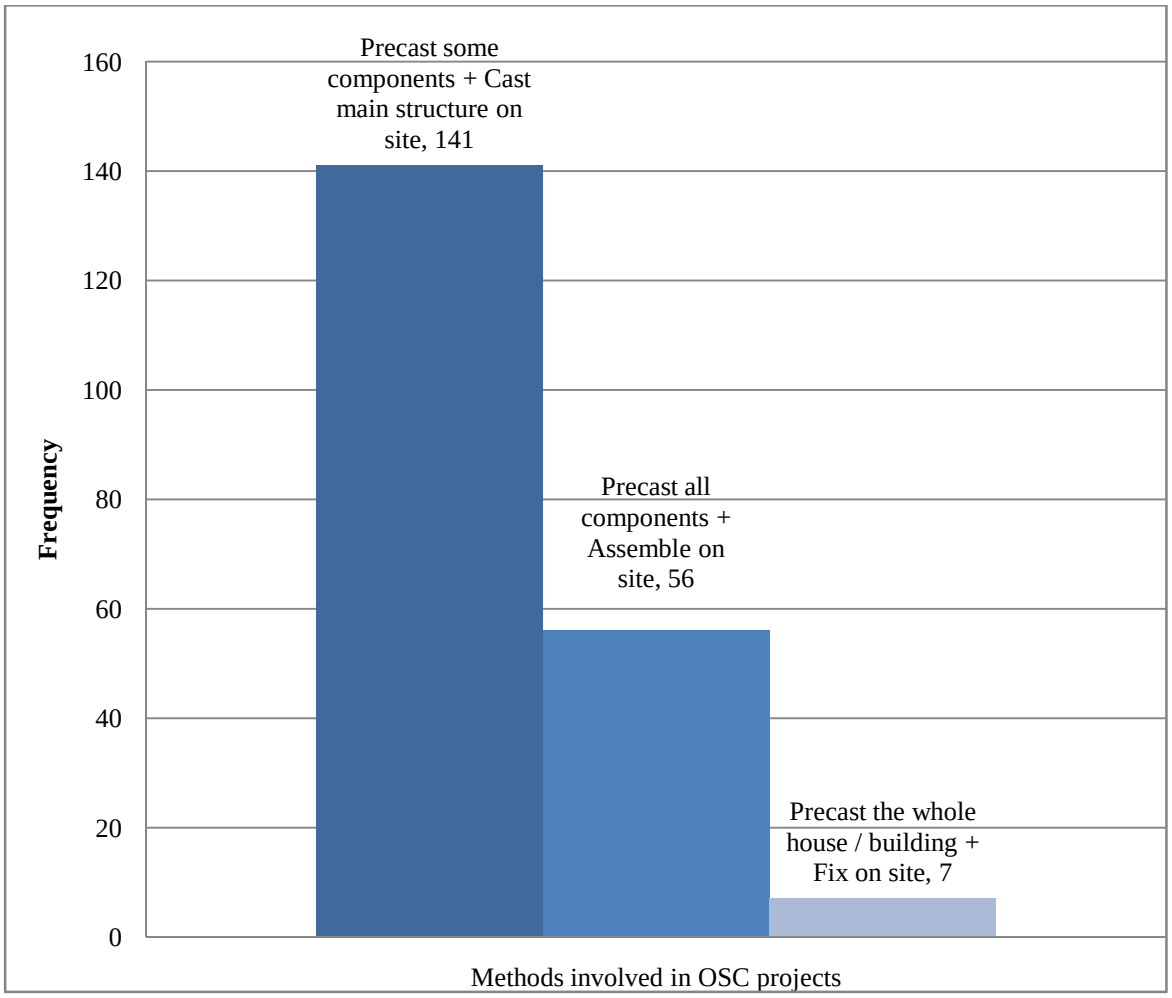


Figure 4.8. Methods involved in the current Off-Site Construction projects, India

4.2.9. Current usage of offsite techniques in the sub-sectors of construction

Respondents were asked to rate the current usage of OSC techniques in various sub-sectors (as shown in the figure below) of the construction projects. According to the current responses, OSC techniques are highly used in factories/warehouses/industrial buildings (75) and office buildings (70). However, amongst these two, factories/warehouses were rated very highly by major number of respondents (Table.4.9). At the same time, 103 participants expressed the fact that OSC techniques are at very low usage in private housing sector. The figure and table below show the responses with a combination of very low usage +low usage and very high usage +high usage remarks.

Table 4.9. Statistical representation of respondents rating for current use of Offsite techniques in various sub-sectors

Name of the subsector	Very low usage	Low usage	Average usage	High usage	Very High usage	Very low and low	Very high and High
Public / Low cost housing	13	43	85	55	8	56	63
Private housing	38	65	57	32	12	103	44
Office Buildings	21	43	70	41	29	64	70
Hospitals / Health	20	63	75	36	10	83	46
Educational Institutions	17	80	74	25	8	97	33
Factories / Warehouses / Industrial Buildings	15	42	72	54	21	57	75
Public Buildings	23	52	73	47	9	75	56
Hotels / Leisure	18	68	78	31	9	86	40
Restaurants / Fast food	23	61	66	42	12	84	54
Supermarkets / Malls / Retails	23	45	74	56	6	68	62

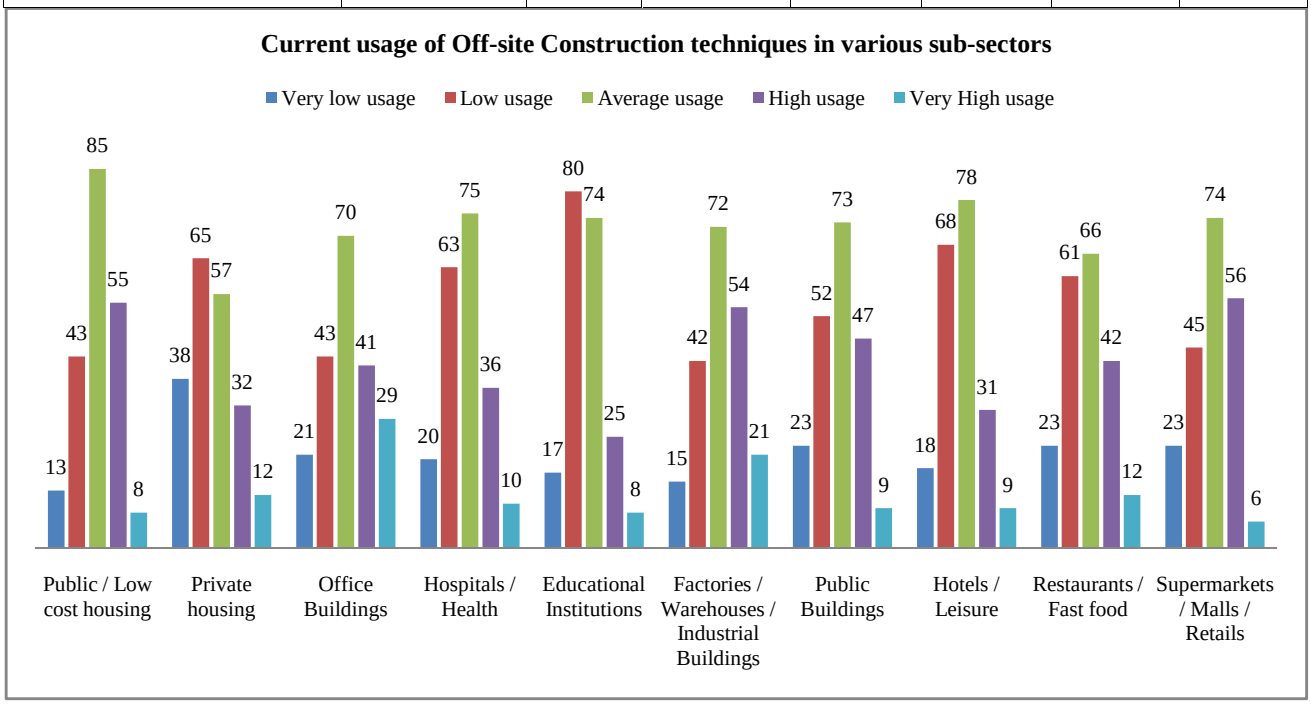


Figure 4.9. Graphical representation of current use of OSC techniques in various sub-sectors in India.

4.2.10. Types of Off-Site Construction products/systems used/planning to use

Here, 89 participants have used a non-load bearing wall panel in the past, while 95 participants consider using a load-bearing wall panel in future projects. Thus, in the data collected, non- load bearing wall panel systems are highly marked as the system most used in current practice. The, 94 professionals consider using volumetric modular buildings in the future projects. On the contrary, 51 professionals have not considered volumetric modular buildings and 31 were not even aware of these systems. Similarly, 76 participants consider using a precast floor and hollow core slab for the future use, while 72 are not interested in these systems. The demographics of the participants' response regarding the various systems is shown in the table and figure below.

Table 4.10. Types of Offsite systems used / planning to use

Types of Off-Site Construction systems	**Not aware**	**Not considering using in future**	**Used in past / Currently using**	**Considering using in future**
Load bearing wall panel	10	62	37	95
Non - Load bearing wall panel	5	27	89	83
Steel and concrete composite panel	5	33	79	87
Cladding systems	18	49	54	83
Precast frame	14	50	56	84
Steel frame	2	43	71	88
Precast floor and hollow core slab	18	72	38	76
Panellised roofing systems	13	62	36	93
Bath / Toilet / Kitchen pods	15	66	39	84
Volumetric modular buildings	31	51	28	94

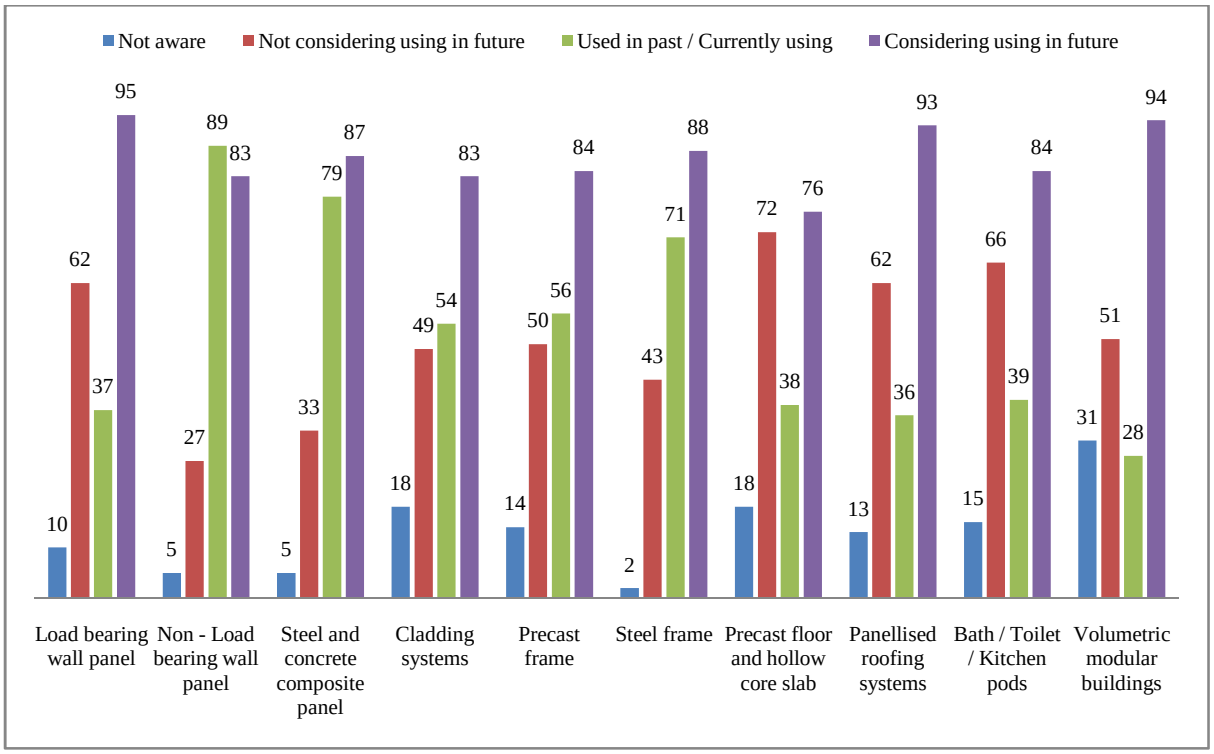


Figure 4.10.Graphical representation of respondents answers on Types of Offsite systems used/planning to use

4.2.11. Comparison of Offsite techniques with traditional construction methods

The respondents were given with a list of variables and asked to respond whether Off-Site Construction practices are significantly worse/worse/same/better/significantly better than traditional construction techniques in the context of each variable. The majority of the respondents agreed that OSC techniques are better in terms of speed in construction against traditional methods. Meanwhile, 91 participants stated that OSC projects are fast when compared to traditional construction methods. On the other hand, Offsite techniques are significantly worse and worse in terms of cost of transportation (119) and flexibility of design (77). The figure below portrays the graphical representation of the responses. In the figure, “offsite techniques are worse” represents both the responses under significantly worse and worse. Similarly, “offsite techniques are better” represents both the responses under ‘significantly better’ and ‘better’.

Table 4.11. Statistical representation of respondents rating of Off-Site construction techniques against traditional construction techniques

Variable	Significantly worse	Worse	Same	Better	Significantly better	Significantly worse and worse	Significantly better and better
Overall cost of construction	19	41	92	39	13	60	52
Cost of transportation	6	113	60	23	2	119	25
Cost of site erection	17	59	74	49	5	76	54
Speed of construction	12	34	67	73	18	46	91
Savings in raw materials	13	42	63	62	24	55	86
Safety	10	50	59	63	22	60	85
Unskilled labour requirement	13	48	67	55	21	61	76
Expertise and experience needed	12	52	69	56	15	64	71
Flexibility of design	16	61	66	46	15	77	61
Equipment usage	13	44	69	64	14	57	78
Logistics planning	5	54	66	60	19	59	79
Ease of erection	15	42	64	62	21	57	83
Final quality	9	53	72	47	23	62	70
Rework and site problems	14	45	80	47	18	59	65

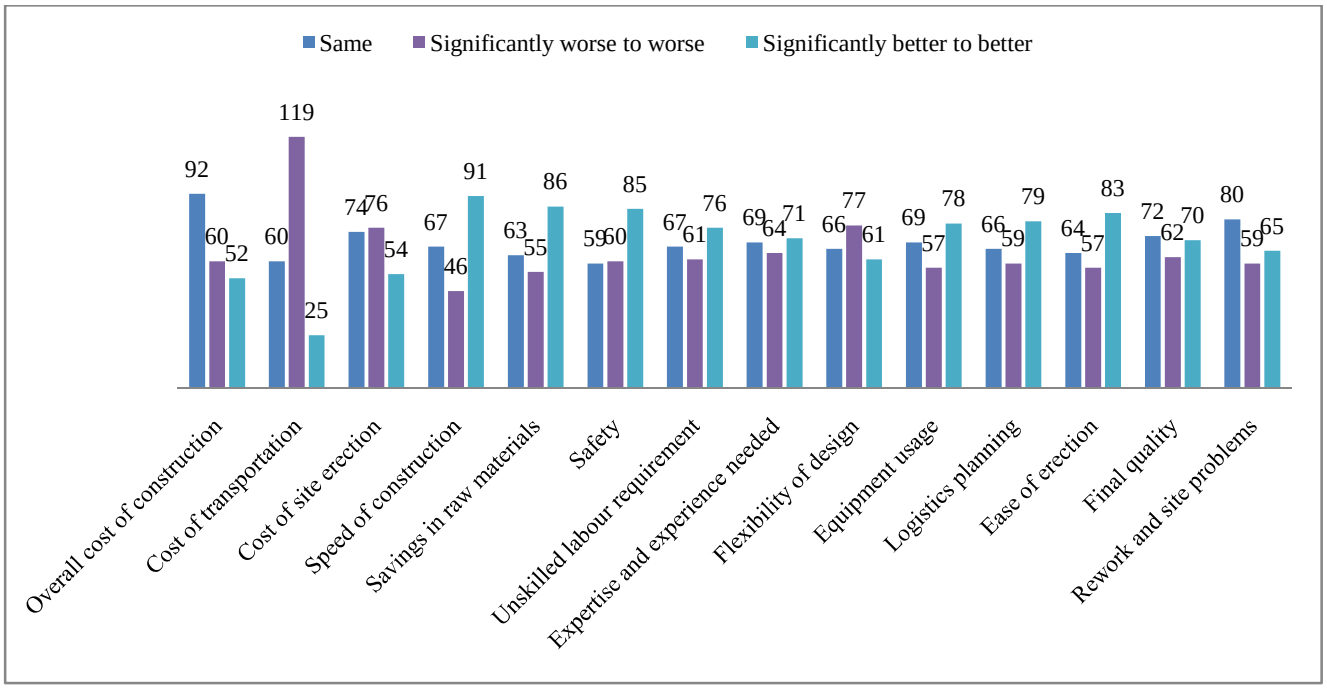


Figure 4.11. Graphical representation of respondents rating Offsite techniques against traditional construction techniques

4.2.12. Influencing factors towards the uptake of Off-Site Construction techniques in India

The researcher has prepared a list of variables from the review of literature. The respondents were asked to rate the influence of each variable in the range of very high/high/moderate influence/low/very low influence. Variables such as ensuring time certainty, speed delivery, minimising on-site duration and lack of transportation & infrastructure facility were highlighted by the majority of the respondents under very high and high influencing factors. According to the data obtained, 130 participants answered that minimising on-site duration has very high to high influence on the Off-Site construction practices in India. Similarly, the availability of codes and standards (132) has had much less influence on the adoption on Off-Site practices in India.

Table 4.12. Influencing factors towards the adoption of Off-Site Construction techniques in India

Variable	Very less influence	Less influence	Moderate influence	high influence	Very high influence	V. Less to less influence	V. High to High influence
Ensuring cost certainty	11	22	98	52	21	33	73
Ensuring time certainty	16	29	70	68	21	45	89
Speed delivery	7	15	56	89	37	22	126
Minimising on-site duration	18	9	47	77	53	27	130
Achieving high quality	19	26	44	72	43	45	115
Addressing the skilled labour shortage	12	20	71	66	35	32	101
Reducing health and safety risks	23	46	60	50	25	69	75
Restricted site specifics	13	31	65	62	33	44	95
Huge demand and delivery requirements	16	30	73	61	24	46	85
Economy of scale	25	30	71	57	21	55	78
Reducing environmental impact during construction	14	38	70	64	18	52	82
Maximising environmental performance in the life cycle	12	23	89	66	14	35	80
Longer lead times	15	63	73	45	8	78	53
Client resistance and scepticism	16	47	64	57	20	63	77
Lack of guidance and information	23	46	64	47	24	69	71
Few codes and standards available	49	83	42	21	9	132	30
Negative image	17	43	54	73	17	60	90
Not locally available	19	49	66	52	18	68	70
No experience of its use	7	36	71	72	18	43	90
Duties and taxes	27	63	63	38	13	90	51
Complex interfacing in between systems	15	52	72	47	18	67	65
Risk averse culture	17	64	67	45	11	81	56

Variable	Very less influence	Less influence	Moderate influence	high influence	Very high influence	V. Less to less influence	V. High to High influence
Skills shortage	41	74	49	27	13	115	40
Lack of manufacturing capacity	14	59	63	53	15	73	68
Lack of transportation infrastructure	13	53	61	47	30	66	77
Higher capital cost	29	96	42	27	10	125	37

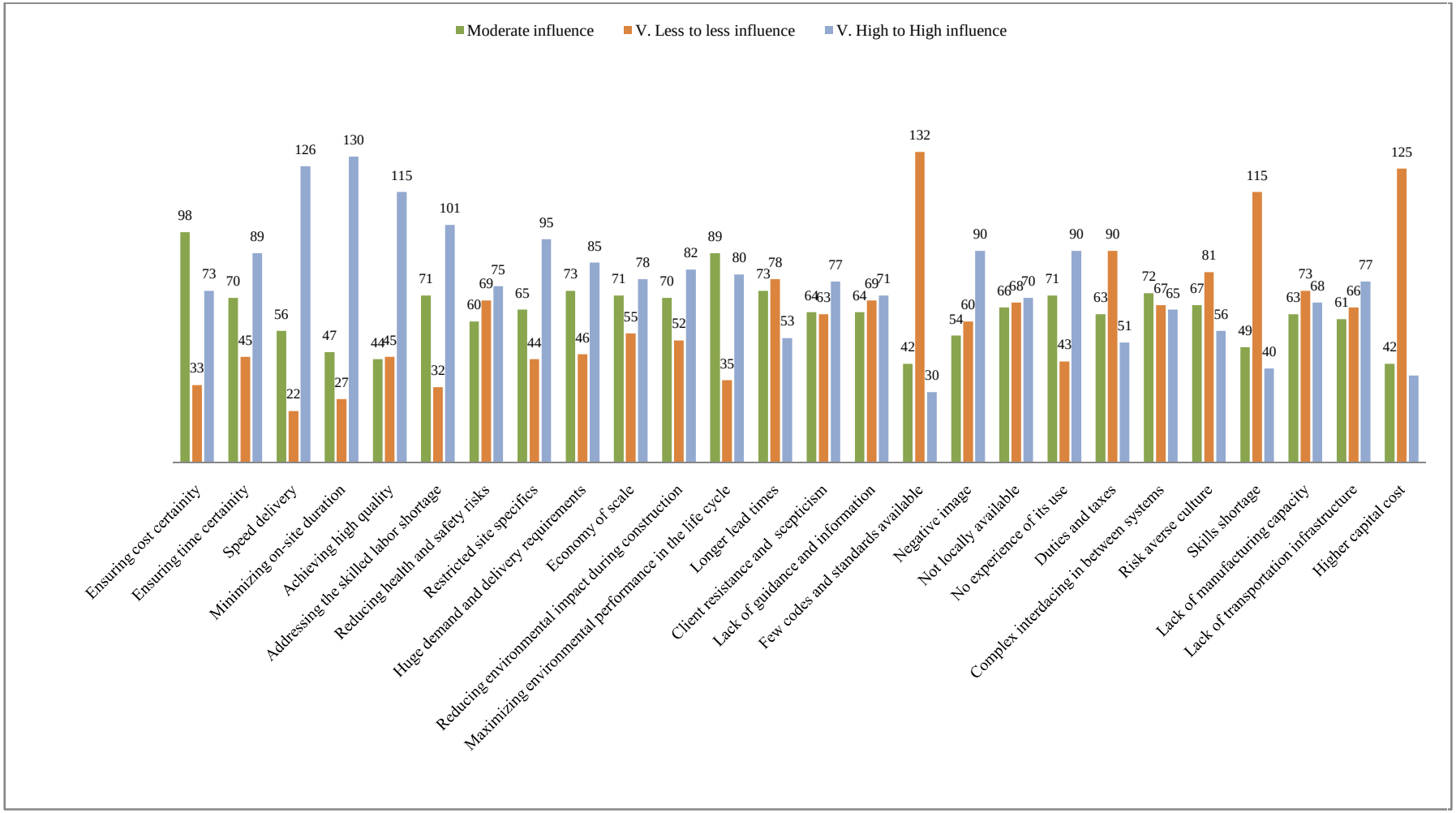


Figure 4.12.Rating of the influencing factors towards the adoption of Off-Site Construction techniques in India

4.2.13. Drivers and barriers

The researcher asked the respondents to select the impact of each variable (whether it encourages/discourages). Based on these responses, the drivers and barriers have been separated and demonstrated in the table below. Amongst the variables, 151 participants felt that "Ensuring cost certainty" encourages the adoption of Off-Site construction techniques in India. Ensuring time certainty has followed this, having 130 participants highlight it as an encouraging attribute. Similarly, in terms of discouraging variables, a risk averse culture was highlighted by 132 respondents. According to the participants, "complex interfacing between the systems", "client resistance and scepticism" and "not locally unavailable" are some of the other barriers. A detail list of drivers and barriers are demonstrated in the table and figure below.

Table 4.13. Results for drivers and barriers towards the adoption of Off-Site construction techniques in India

Variable	Encourages	Discourages
Ensuring cost certainty	151	53
Ensuring time certainty	130	74
Speed delivery	110	94
Minimising on-site duration	119	85
Achieving high quality	113	91
Addressing the skilled labour shortage	123	81
Reducing health and safety risks	110	94
Restricted site specifics	115	89
Huge demand and delivery requirements	105	99
Economy of scale	111	93
Reducing environmental impact during construction	106	98
Maximising environmental performance in the life cycle	115	89
Longer lead times	94	110
Client resistance and scepticism	77	127
Lack of guidance and information	94	110
Few codes and standards available	105	94
Negative image	95	109
Not locally available	79	125
No experience of its use	83	121
Duties and taxes	84	120
Complex interfacing in between systems	76	128
Risk averse culture	72	132
Skills shortage	116	88

Lack of manufacturing capacity	95	109
Lack of transportation infrastructure	80	124
Higher capital cost	89	115

Table 4.14. Drivers and barriers towards the adoption of Off-Site construction techniques in India

• Ensuring cost certainty	DRIVERS
• Ensuring time certainty	
• Speed delivery	
• Minimising on-site duration	
• Achieving high quality	
• Addressing the skilled labour shortage	
• Reducing health and safety risks	
• Restricted site specifics	
• Huge demand and delivery requirements	
• Economy of scale	
• Reducing environmental impact during construction	
• Maximising environmental performance in the life cycle	
• Few codes and standards available	
• Skills shortage	
• Longer lead times	BARRIERS
• Client resistance and scepticism	
• Lack of guidance and information	
• Negative image	
• Not locally available	
• No experience of its use	
• Duties and taxes	
• Complex interfacing in between systems	
• Risk averse culture	
• Lack of manufacturing capacity	
• Lack of transportation infrastructure	
• Higher capital cost	

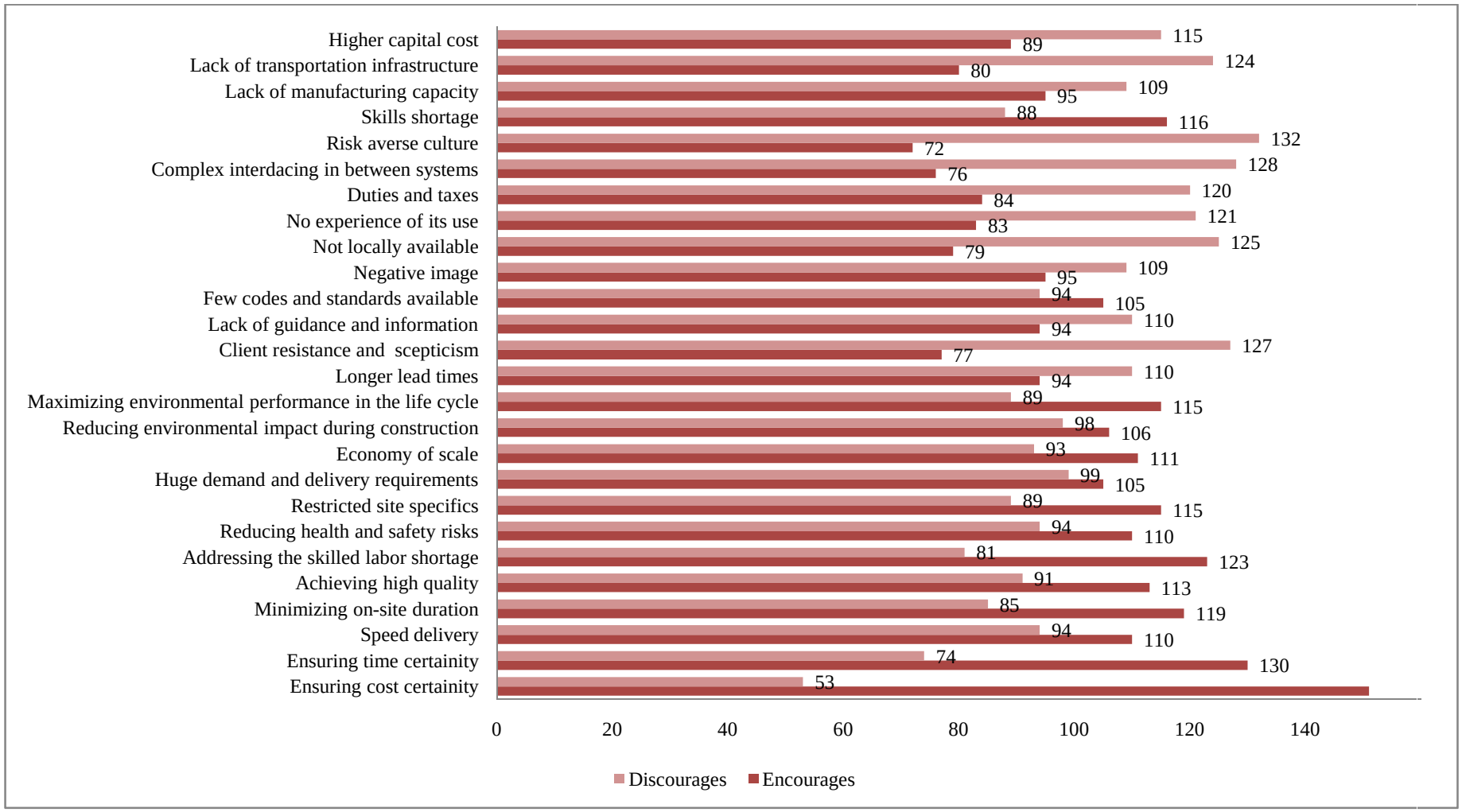


Figure 4.13. Drivers and barriers towards the adoption of OSC in India

4.2.14. Current availability of information on offsite techniques

This question sets out to know the current availability of literature and information on Offsite techniques in India. Here, 127 participants highlighted that technical research reports are scarcely available in India. In addition, 80 participants marked that successful case studies/best practices on Off-Site construction techniques are currently unavailable in India. Furthermore, 87 participants answered that technical manuals/designs are widely available in India. The table and figure below describe the tendency of availability of information on Off-Site construction techniques in India.

Table 4.15. Current availability of information on Off-Site construction techniques

Variable	Not available	Scarcely available	Widely available
Successful case studies / Best practices	80	107	17
Technical manuals / designs	19	98	87
General web resources	23	107	74
Technical research reports	29	127	48
Government and legislative sources	40	108	56
Workshops / Training sessions	55	120	29

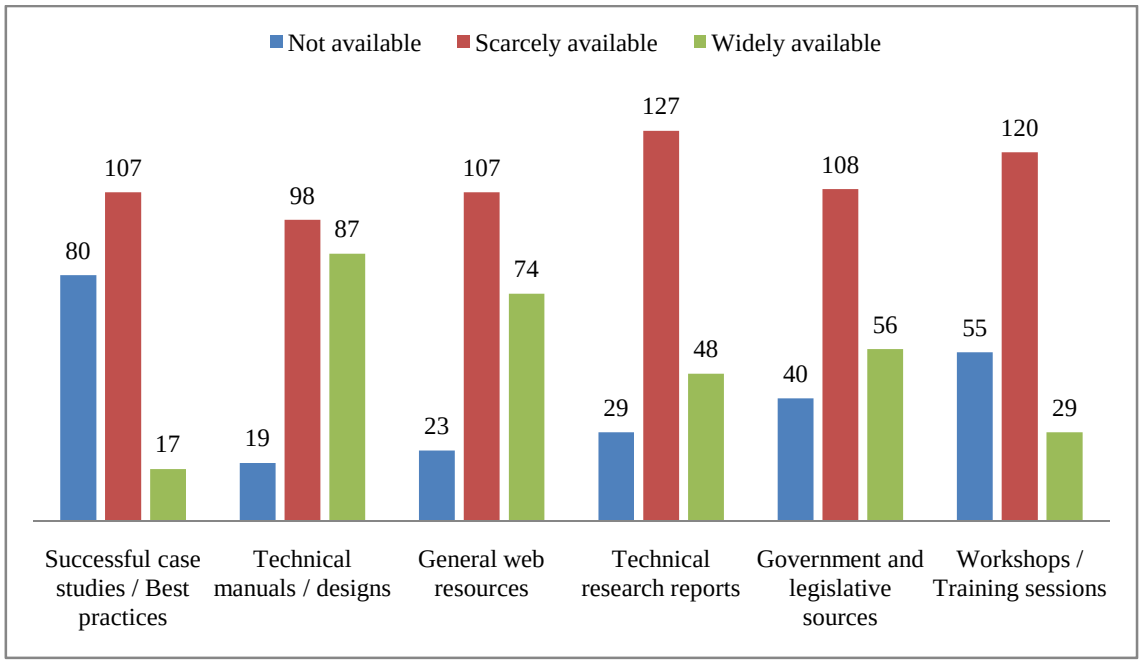


Figure 4.14. Current availability of information on Off-Site construction techniques

4.3. Factor Analysis using SPSS

The main purpose of factor analysis is to investigate potential relationship between variables, in order to group them into factors. According to Field (2005), factor analysis reveals the measuring aspects of various variables. In our current research, the researcher identified 26 variables from the literature review and listed the same variables in the questionnaire. After factor analysis, the number of variables was reduced to 17. In addition, these variables are categorised into four (4) groups. The results of factor analysis of current research are explained in the next paragraphs.Going into details, the researcher conducted Principal Component Analysis. The researcher has forced the number of factors to four (4) and adopted the maximum likelihood method with the varimax rotation technique. These details, along with the results, are shown in the table below.

Table 4.16. Rotated Component Matrix

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Complex interfacing between systems	.712	.265	.024	.033
Duties and Taxes	.704	.145	-.034	-.156
No experience of its use	.684	.222	.046	-.067
Risk averse culture	.625	.208	-.265	-.113
Longer lead times	.621	.152	-.187	.061
Client resistance & scepticism	.567	.360	-.112	-.208
Lack of guidance and information	.519	.466	-.113	-.038
Lack of transportation infrastructure	.124	.804	-.009	-.036
Lack of manufacturing capacity	.192	.670	-.246	-.025
Not locally available	.368	.586	-.049	-.023
Few codes/standards available	.464	.563	.063	-.109
Negative image	.435	.551	-.031	-.354
Higher capital cost	.458	.548	-.034	-.108
Ensuring cost certainty / Reliability in cost	-.097	.006	.807	-.118
Ensuring time certainty	-.070	-.214	.717	.293
Minimizing on-site duration	-.047	-.130	-.112	.826
Speed delivery	-.137	.011	.437	.716

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

4.3.1. Rotated Component Matrix

Rotated Component Matrix shows the factor loading for individual variables with respect to the factor (Tang, L., & Shen, Q, 2013). The Rotated Component Matrix provided in the table above has helped in grouping the 17 variables into five factors. This grouping is performed based on the loadings for all 17 variables exceeding 0.5 ($p < 0.01$). Hence, each group was separated based on the loadings of more than 0.5. According to this, the complex interfacing between systems, duties and taxes, no experience of its use, risk averse culture, longer lead times, client resistance and scepticism and the lack of guidance and information are rewarded under Factor -1 (yet to name this). Similarly, the lack of transportation infrastructure, the lack of manufacturing capacity, the lack of local availability and the few codes/standards being available, the negative image and higher capital cost are loaded on Factor-2 (yet to be named). Other factors, such as ensuring cost certainty and ensuring time certainty, minimising on-site duration and speed delivery, are rewarded under Factor-3 and Factor-4, respectively.

4.3.2. Reliability Analysis for factors formed through factor analysis

Reliability analysis test is conducted for each individual factor, with the respective variables. Cronbach's Alpha is used to test the reliability of each factor.

Factor-1:

Table 4.17. Reliability Analysis of Factor-1

Reliability Statistics

Cronbach's Alpha	N of Items
.828	7

The Cronbach's alpha for Factor-1 with 7 items is 0.828. This is exceeding 0.7, which is considered as acceptable. Hence, the factor-1 has high internal consistency and reliability.

Factor-2:

Table 4.18. Reliability Analysis of Factor-2

Reliability Statistics

Cronbach's Alpha	N of Items
.820	6

The Cronbach's alpha for Factor-2 with 6 items is 0.820. Hence, the factor-2, also has high internal consistency and reliability.

Factor-3:

Table 4.19. Reliability Analysis of Factor-3

Reliability Statistics

Cronbach's Alpha	N of Items
.500	2

The Cronbach's alpha for Factor-3 with 2 items is 0.5. Although this is less than the bench mark 0.7 because it lies between 0.5 to 0.7, the items still represent an acceptable level of internal consistency and reliability (Yusoff, M. S. B., 2012). Hence, Factor-3 has acceptable level of reliability.

Factor-4:

Table 4.20. Reliability Analysis of Factor-4

Reliability Statistics

Cronbach's Alpha	N of Items
.514	2

The Cronbach's alpha for Factor-4 with 2 items is 0.514. Following the acceptable range of Cronbach's alpha i.e. 0.5 – 0.7, the items in Factor-4 represent acceptable level of internal consistency and reliability.

4.4. Descriptive Statistics

After the factor analysis, the second output from the analysis is a table of descriptive statistics for all variables under investigation. The following table presents the mean, standard deviation and the number of respondents (N) who participated in the survey. According to this analysis, the highest mean is 3.91, and thus the most significant variable is "minimising on-site duration". In addition, all the variables scored the mean value higher than 1, which indicate that all the extracted variables have impact on the practice of Off-Site Construction in India.

Table 4.21. Descriptive Statistics of variables under investigation

Variable	N	Mean	Std. Deviation
Ensuring cost certainty / Reliability in cost	204	3.18	.755
Ensuring time certainty	204	3.44	.843
Minimizing on-site duration	204	3.91	.883
Complex interfacing between systems	204	2.43	1.096
Duties and Taxes	204	2.48	1.103
No experience of its use	204	2.48	1.071
Risk averse culture	204	2.55	1.023
Longer lead times	204	2.84	.977
Client resistance & scepticism	204	2.40	1.155
Lack of guidance and information	204	2.52	1.292
Lack of transportation infrastructure	204	2.43	1.127
Lack of manufacturing capacity	204	2.47	1.129
Not locally available	204	2.43	1.036
Few codes/standards available	204	2.31	1.077
Negative image	204	2.40	.985
Higher capital cost	204	2.48	1.048
Speed delivery	204	3.74	.859

4.5. The Correlation Matrix (R- Matrix)

A correlation matrix is a rectangular array of numbers which gives the correlation coefficients between a single variable and other variables. The sign of the correlation coefficient determines whether the correlation is positive or negative between the variables. Of all the variables, minimising onsite duration has the negative correlation with the rest. The table showing correlation matrix can be found in Appendix E.

4.6. Communalities

The Table 4.22 presents the communalities before and after extraction. The principal component analysis works on the initial assumption that all variance is common. Hence, before extraction, the communalities are 1. The actual variance in reality is shown after extracting the variables. For instance, as can be seen from the results below, it is understood that 63% is common, or shared variance of the factor "Speed delivery". The amount of variance in each factor that can be explained by the retained factors is represented by the communalities after the extraction (Kinnear and Gray, 2004).

Table 4.22. Communalities

Communalities		
	Initial	Extraction
Ensuring cost certainty / Reliability in cost	1.000	.527
Ensuring time certainty	1.000	.617
Speed delivery	1.000	.630
Minimizing on-site duration	1.000	.639
Longer lead times	1.000	.546
Client resistance & scepticism	1.000	.550
Lack of guidance and information	1.000	.512
Few codes/standards available	1.000	.612
Maximizing environmental performance during the life cycle	1.000	.605
Not locally available	1.000	.494
No experience of its use	1.000	.458
Duties and Taxes	1.000	.546
Complex interfacing between systems	1.000	.573
Risk averse culture	1.000	.502
Lack of manufacturing capacity	1.000	.429
Lack of transportation infrastructure	1.000	.625
Higher capital cost	1.000	.514
Extraction Method: Principal Component Analysis.		

4.7. KMO and Bartlett's Test

This test is conducted to know the measure of sampling adequacy and the reliability of the factor analysis. The output of this test contains the Kaiser-Meyer-Olkin measure of sampling adequacy and Barlett's test of sphericity. According to Kaiser, the value with more than 0.5 represents good number of sample. In current research, the obtained KMO value is 0.868. Further, the Barlett's test for current research is highly significant with the p value less than 0.001 ($p<0.001$). Hence, it can be said that the research has good sample size and it is also adequate for factor analysis.

Table 4.23. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Adequacy.	Measure of Sampling	.868
Bartlett's Test of Sphericity	Approx. Chi-Square	1631.567
	df	325
	Sig.	.000

4.8. Total Variance Explained

The Table 4.24 shows eigenvalues of each variable before extraction, after extraction and after rotation. Rotation thus optimises the structure and it also equalises the relative importance of the factors. The eigenvalues of each variable represents the respective variance by the linear component and the percentage of variance. In the current research, the first component explains 35.733% total variance. From the table below, it can be observed that the first few factors explain relatively large amounts of variance compared with the subsequent factors that have small amounts of variance. Now, extracting sums of square loadings, the second block with three columns repeats the output of the first block, but only for the four factors that meet Kaiser's criterion.

Table 4.24. Total Variance Explained

Component	Initial Eigenvalues			Extraction sums of squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.075	35.733	35.733	6.075	35.733	35.733	3.677	21.632	21.632

2	1.574	9.257	44.990	1.574	9.257	44.990	2.978	17.520	39.152
3	1.159	6.820	51.810	1.159	6.820	51.810	1.571	9.244	48.396
4	.956	5.626	57.436	0.956	5.626	57.436	1.537	9.040	57.436
5	.859	5.052	62.488						
6	.780	4.590	67.078						
7	.770	4.530	71.608						
8	.670	3.941	75.550						
9	.636	3.741	79.291						
10	.591	3.475	82.766						
11	.573	3.368	86.134						
12	.474	2.786	88.919						
13	.428	2.515	91.434						
14	.391	2.300	93.734						
15	.377	2.218	95.952						
16	.360	2.117	98.069						
17	.328	1.931	100.000						

4.9. Scree Plot

The Scree plot is a graph of the eigenvalues which is plotted against the ordinal numbers of the factors extracted (Kinnear and Gray 2004). The graph is useful to determine the remaining factors. The point of interest is where the curve begins to flatten out. From the following graph, it is understood that the curve starts to flatten between the components 5 and 6. Hence only four factors will be used for relationship analysis.

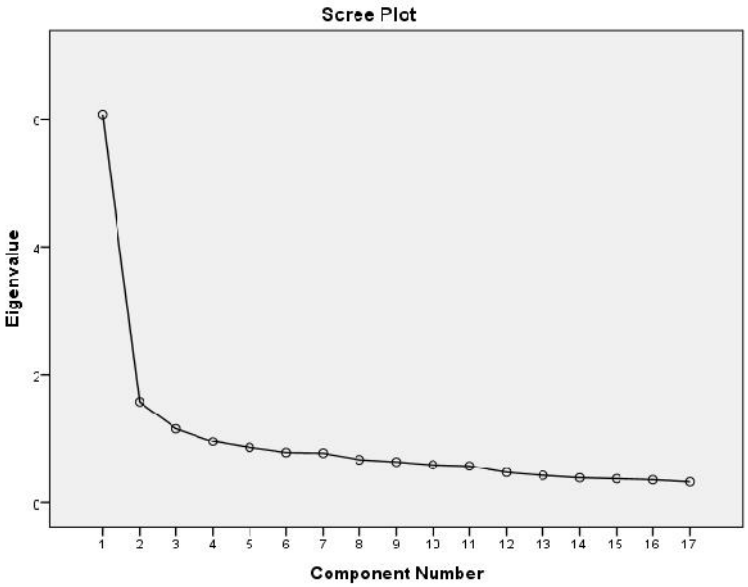


Figure 4.15 Scree plot

The next section provides the development of framework on the basis of the literature review and data analysis. It presents the discussion of the key themes and findings that originated from the literature review, as well as findings from the data collection. The main aim of this research is to develop an Off-Site Construction readiness framework for Indian construction organisations, with a view to enabling the effective adoption of OSC techniques in current construction organisations.

4.10. Key steps involved in developing the conceptual framework

The researcher conducted a multi-stage exercise in order to develop the conceptual model. These steps comprised:

- ***Thorough literature review:*** The researcher conducted a thorough review of the literature in order to understand and document the Off-Site Construction paradigm and its practices. Further, various variables that affect the adoption of OSC were identified. Similarly, a list of Critical Success Factors (CSFs), drivers and barriers were extracted from the literature.

- ***Briefing the findings of literature:*** In the literature, a significant number of variables were repeatedly discussed in the context of different countries. Hence, in the second stage the researcher followed a process of careful

filtering, reducing the high number of variables to a reasonable number. In particular, the researcher combined or eliminated some variables that addressed the same content with different labels. For instance, the two variables 'ensuring cost certainty' and 'reliability in cost' addressed the same issue, though titled differently. After this exercise, the researcher designed a questionnaire with a list of variables that formed a basis for the investigation in India.

- ***Questionnaire survey:*** The researcher conducted a questionnaire survey to identify the influencing factors from the viewpoint of construction organisations in India. The results from the questionnaire recognised seventeen factors that are crucial in the context of India. These will be discussed in detail in the following sections.

- ***Review of the existing readiness models in construction and other similar industries, and conceptual models for OSC practice and performance:*** The researcher thoroughly reviewed the currently available readiness models in the construction and other industries (see Chapter 2). Additionally, the author studied the conceptual models developed regarding the OSP patterns of concern (Nadim & Goulding, 2011), OSC interrelationships (Goulding & Arif, 2013) and core issues in OSC practices (Goulding, Rahimian et al., 2012).

The literature review and data analysis from the questionnaires helped the researcher to identify the key factors that have significant influence on the Off-Site Construction (OSC) readiness of the construction organisations. Further, the factor analysis enabled the researcher to group the sub-factors under the relevant key factors (Table 4.26). In the next stage, the researcher developed a conceptual framework (Table 4.27) to assess the OSC readiness of construction organisations. The researcher initiated the process by listing the key factors (F1: Operational challenges, F2: Strategy, F3: Certainty planning and F4: Operational efficiency) and the respective components of the key factors, along with the definitions. In the next phase, in order to assess the OSC, three pre-defined maturity levels were introduced into the framework. These maturity levels were carefully developed on the basis of the literature review. The first maturity level indicates those organisations that partly

followed the critical steps involved in the effective implementation of OC techniques. The second maturity level indicates how frequently OSC methods were applied in the organisation. Further, this level also highlights the need for standardisation in the operations, to ensure optimal implementation of OSC techniques in the organisations. The third maturity level indicates the strong established status of operational procedures in the organisations. This conceptual framework required further refinement to overcome the practical difficulties in the Indian construction organisations. In the next step, the researcher refined the conceptual OSC framework by using the data obtained.

Table 4.25. List of Factors and Sub-factors from the data analysis

FACTOR 1	Complex interfacing between the systems
	Duties and taxes
	No experience of its use
	Risk-averse culture
	Longer lead times
	Client resistance & scepticism
	Lack of guidance and information
FACTOR 2	Lack of transportation infrastructure
	Lack of manufacturing capacity
	Not locally available
	Few codes / standards available
	Maximising environmental performance in the life cycle
	Higher capital cost
FACTOR - 3	Ensuring cost certainty
	Ensuring time certainty
FACTOR 4	Minimising on-site duration
	Speed of delivery

4.11. Definition of Sub-factors

4.11.1. Factor 1. Operational challenges

This factor significantly deals with the challenges associated with Off-Site Construction working methods. Hence, it is named as ‘operational challenges’. The indicators asses the readiness of any organisation, based on the efficiency of the organisation in addressing these challenges. An effective performance of this factor enables successful application of Off-Site Construction practices in the organisation.

4.11.1.1. Indicators in Operational challenges

F1 – 1. Complex interfacing between the systems: The connections between various systems and individual products are complex in Off-Site Construction processes. This factor also demands special attention from the designers who must fulfil exact requirements of bespoke joints and fittings. Further, the workforce also needs to be trained to work on these systems during on-site activities.

F1 – 2. Duties and taxes: This indicator deals with various excise and custom duties levied on the systems manufactured in the country or exported from foreign countries. It also deals with the taxes payable at various points during the construction process.

F1 – 3. Level of experience: This addresses the level of experience of the organisation or of the key players of the organisation, in the area of Off-Site Construction.

F1 – 4. Risk-averse culture: This deals with the existing negative image of Off-Site Construction. This indicator assesses the approach of the organisation in addressing the existing cynicism regarding the usage of Off-Site Construction methods.

F1 – 5. Longer lead times: This indicator assesses the capability of the organisation to deal with delays between the initiation and execution of the process.

F1 – 6. Client resistance and scepticism: This deals with the approaches used to address the resistance from clients towards the application of a new concept, i.e. Off-Site Construction.

F1 – 7. Lack of guidance and information: This indicator assesses the current practices of the organisation in providing guidance and information regarding Off-Site Construction methods. In the first stage of data collection (the questionnaire), the majority of the respondents highlighted the lack of guidance and information available for Off-Site Construction methods in India. Thus, this indicator assesses the level of support and guidance provided to the staff and other stakeholders of the organisation, in terms of the application of various Off-Site Construction methods.

4.11.2. Factor 2: Strategy

This factor stresses the strategic indicators that are critical for Off-Site Construction. Effective application and performance of the indicators in this factor enables the successful application of Off-Site Construction practices in the organisation.

4.11.2.1. Indicators in Strategy

F2 – 1. Transportation infrastructure: This indicator describes the planning and co-ordination of transporting various off-site systems, to be executed in various projects by the organisation. The OSC readiness of any organisation is significantly influenced by the level of transportation planning.

F2 – 2. Manufacturing capacity: This indicator deals with issues such as the volume of products that can be generated by a production plant or a company within the available time and resources. This also examines the organisation's planning and utilisation of the manufacturing facilities.

F2 – 3. Local availability: This indicator deals with the utilisation of OSC products that are available in the local market. Also, if the required systems or products are unavailable, this indicator investigates the strategies deployed by the organisation.

F2 – 4. Codes / standards available: This indicator deals with the set of technical guidelines that function as instructions for designers, operators and other construction workforce members who deal with Off-Site Construction practices in the organisation. An effective implementation of this indicator ensures that the Off-Site Construction activities comply with required standards. It also helps to protect clients or end users by providing high-quality services and goods.

F2 – 5. Environmental impact during construction: This indicator treats the impact of various construction activities, such as site preparation, clearance, traffic of equipment, on the environment. It also highlights the noise impact, road safety issues and other measures to be considered by the organisation during the construction.

F2 – 6. Capital cost: This indicator deals with the strategies and financial preparedness of the organisation in terms of its capital investment.

4.11.3. Factor 3: Certainty planning

The certainty planning factor investigates the level of efficiency achieved by the organisation through planning various activities and cost schedules, in order to enable the optimal use of different Off-Site Construction techniques.

4.11.3.1. Indicators in Certainty planning

F3 – 1. Cost certainty: This indicator stresses the planning, monitoring and controlling of the costs of various off-site projects by the organisation. An effective implementation of this indicator ensures cost certainty.

F3 – 2. Time certainty: This indicator emphasises the effective use of time planning and the scheduling of various activities involved in the Off-Site Construction projects. The indicator evaluates the methods adopted by the organisations in terms of time planning, in order to maximize the certainty of schedules and completion.

4.11.4. Factor 4: Operational impact

This factor involves the indicators that measure the impact of the implementation of Off-Site Construction techniques by the organisation. Effective planning and execution of this factor results in the successful application of OSC.

4.11.4.1. Indicators in Operational impact

F4 – 1. Minimising on-site duration: This indicator stresses the effective co-ordination and execution of various activities during planning and construction.

F4 – 2. Speed of delivery: This indicator evaluates whether the products and services are properly planned to be delivered on site. Such speed and promptness in delivery enables the smooth flow of the project.

Table 4.26. List of factors with the proposed names

Operational challenges	Complex interfacing between the systems
	Duties and taxes
	Lack of experience
	Risk-averse culture
	Lead times
	Client resistance & scepticism
	Lack of guidance and information
Strategy	Lack of transportation infrastructure
	Manufacturing capacity
	Local availability
	Few codes / standards available
	Maximising environmental impact during construction
	Capital cost
Planning certainty	Cost certainty
	Time certainty
Operational impact	Minimising on-site duration
	Speed of delivery

Factors	Level 1	Level 2	Level 3
	NO CLEAR APPLICATION	**FREQUENT APPLICATION. NO POLICY / LACK OF POLICY**	**ESTABLISHED POLICY**
	The organisation may / may not practice the critical steps for effective implementation of Off-site techniques. Organisations at this level need to re- visit their existing operations and re – structure their team to improve efficiency / readiness.	This level represents the frequency of application. At this level, the organisation significantly repeats a series of critical techniques. However, it will have scope for improvement in processes and need to define strategy / policy.	At this level, the organisation has clear policy about Off-Site Construction practices. It constantly reviews the existing operations, and plans the project strategies to increase efficiency. The organisation at this level, document best practices through recording experiences and lessons from the previous projects.
F1. Operational challenges			
F1. 1. Complex interfacing between the systems: How does the organisation respond to the challenges in assembling individual systems / products of a complex nature?	Is the workforce aware of the assembling techniques and interfacing of different products?	Does the organisation demonstrate how to assemble new, complex structures before erecting them on – site?	Does the organisation expedite the learning curve from one off-site project to another project, through integrating training programs in the strategy? Also, does the organisation prioritise capacity building in the policy?
F1.2. Duties and taxes: How does the organisation minimize or plan to reduce incurring duties and taxes on the off-site products?	Does the organisation attempt to learn about the potential duties and taxes on the products to be used?	Does the organisation import none /fewer products and procure more products from local manufacturers? Also, does the organisation maintain any records of the duties and taxes payable / already paid?	Does the organisation balance utilisation of imported and local products? And, does it repeatedly source for products which are entitled to tax exemptions / incentives?

F1.3. Level of experience in Off-Site construction: How many off-site projects have been handled? What is the level of expertise of the organisation?	Are the design and project development teams well aware of techniques and methods involved in off-site construction practices?	Do all the senior management, project teams, construction workforce have significant experience in handling off-site construction projects?	Does the organisation maintain a structure with dedicated project team and workforce that are specialised in off-site construction operations?
F1.4. Attitude towards risk: How does the organisation handle the existing negative image (Goodier & Gibb, 2007; Arif. M *et. al.*, 2012) on off-site construction methods?	Does the organisation promote the potential benefits from off-site construction methods? Also, does the organisation conduct any enlightenment programs / one to one sessions with the potential clients to clarify their concerns?	Does the organisation maintain a calendar of awareness workshops? Also, does it brief the potential clients about the nature of work, application methods and achievable benefits before starting the project?	Does the organisation extensively promote the benefits of OSC products by showcasing successful projects, cost break-up and product samples? Also does it include the promotional activities in the strategy?
F1.5. Lead times: What is the capability of the organisation in avoiding delays caused by long lead times?	Does the organisation consult the manufacturers before planning all critical events in the project schedule?	Are all events planned according to the delivery schedules, to avoid time lags between the commencement and completion of the project?	Does the organisation closely work with manufacturers and all the supply chain involved in the projects? Also, does it collaborate with manufacturers and facilitate an in-house set up for greater control on time schedules?

F1.6. Client resistance and scepticism: How does the organisation address the resistance from clients?	Does the organisation explain to the client about the potential benefits of using OSC methods?	Does the organisation assure client about the added advantages with clear estimates and documentation along with detailed project plan?	Does the organisation involve client in key decision making process and clarify any concerns with clear evidence / past success stories? Also, does the organisation showcase successful projects and communicate the client about the progress of critical events with detailed documentation?
F1.7. Guidance and information: To what extent, does the organisation support the staff with guidance and information on off-site construction techniques?	Is the workforce in the organisation provided with training, technical manuals and literature on new products? Also, is this accessible to the entire workforce?	Does the organisation arrange workshops and dedicated training from the manufacturers before implementing any new projects?	Does the organisation have dedicated resources (instructor, technical team, library, training room, facilities which enable audio- visual demonstration) for training and guidance?
F2. Strategy			
F2.1. Transportation infrastructure: What are the plans and arrangements made by the organisation to address the problems raised due to the existing poor road and transportation network?	Is the organisation aware of the minimum requirements to transport materials used in off-site construction projects?	If yes, does it critically evaluate the existing road and transportation network and customise their procurement strategy accordingly?	Does the organisation co-ordinate with the manufacturers at the initial stage and document route plan and schedules before placing the order (or) before starting the project?

F2.2. Manufacturing facility: How does the organisation handle the volume of products and other resources required?	Does the organisation estimate the requirement / quantities and consult the manufacturing facility before starting construction?	If yes, does the organisation complete the selection process at the early stage and place orders with effective planning?	Does the organisation evaluate the capacity of manufacturers to meet demand? Also, does the organisation enter into agreements with supply contracts?
F2.3. Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers to transfer and utilise their technology?
F2.4. Availability of codes / standards: The extent to which the organisation provide guidelines to the designers, operators and other construction workforce.	Are there any written standards/ guidelines available to all the members in project team?	Does the organisation strictly follow the standards throughout the design and construction stages?	Does the organisation document the instructions before design and monitor the activities to ensure compliance with the standards?
F2.5. Maximizing environmental performance in the life cycle: To examine the strategies deployed by the organisation to maximize the usage of sustainable products and processes in various projects.	Is the organisation aware of the off-site products that are sustainable? If yes, does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimising waste during construction, etc.) at the beginning of project?	Does the organisation establish a policy to use only certified or sustainable products recommended by standard organisations? Does the organisation also register for sustainable building certification?

F2.6. Capital cost: What is the financial preparedness of the organisation in terms of the capital investment?	Does the organisation allocate dedicated funds to support and accelerate the adoption of off-site construction techniques?	If yes, does the organisation maintain a financial strategy for future investments?	Does the organisation establish a policy on the investment diversification and strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?
F3. Certainty planning			
F3.1. Cost certainty: To what extent, does the organisation plan and monitor the budget performance?	Does the organisation document the estimates at the beginning of the project? Also, is there any evidence of integration between project administration and control?	If yes, does the organisation closely monitor the project expenses and compare with the estimates? Also, does it take measures to avoid any variation?	Does the organisation implement a standardised project financial accounting and management systems?
F3.2. Time certainty: How does the organisation plan the critical activities? What is the capability of the organisation to ensure that there is no variation between the estimated and actual completion date?	Does the organisation identify critical activities and follow their sequence of execution?	Does the organisation monitor and review on-site activities and take precautions to avoid any delay?	Does the organisation establish a policy to optimise performance through ensuring process standardisation?

F4. Operational efficiency			
F4.1. Minimizing on-site duration: What is the capability of the organisation to reduce / minimize the duration of non-critical activities during construction?	Does the organisation identify and control / avoid the non-critical activities?	Does the organisation efficiently plan and execute all parallel activities?	Does the organisation ensure that all off-site activities are completed before starting erection on construction site? Also, does it standardise the on-site working process?
F4.2. Prompt delivery: How does the organisation ensure prompt delivery of products and services?	Does the organisation closely work with supply chain and logistics involved in various projects?	Does the organisation collaborate with select vendors and consultants involved in various projects?	Does the organisation maintain a directory of efficient vendors and service providers based on their performance? Does it award projects based on their record?

Table 4.27. Conceptual Off-Site Construction readiness framework

4.12. Summary of the interviews

The researcher interviewed five professionals, each with more than 15 years of experience in the Indian construction industry. Each of them also possessed more than five years of experience in working with OSC methods. The duration of each interview was approximately 50 minutes. All the participants were provided with the research information sheet (Appendix- C) at the beginning of the interview.

The researcher designed a semi-structured interview, using six major questions. The first question aimed to investigate the factor groups of the conceptual framework. All the participants were asked to evaluate the classification of factors. All five participants agreed with the current classification of factors. However, one participant suggested revisions in the titles of the factors and sub-factors. This participant suggested renaming the sub-factor F1.4 within Operational challenges as 'Promoting the advantages of OSC techniques'. Also, the participant proposed revisions to the second and third factors. The researcher followed the recommendation, and renamed the factors as 'Broad Execution Strategy' and 'Certainty in planning'. The sub-factor F1.7 was also renamed as 'Guidance and information for field staff'. The second question dealt with the scope and definitions of each sub-factor in the framework. The researcher had explained the scope of each sub-factor to all the participants. However, two participants expressed their disagreement with the scope of the sub-factor 'Duties and taxes'. They restructured the scope, and the researcher agreed with the revisions. The content of maturity levels was addressed in the third question.

In the fourth question, the researcher asked about the adequacy of the number of levels and their appropriateness for assessing the OSC readiness of construction organisations in India. Participants were also encouraged to suggest any alternative numberings, with appropriate reasoning. All the participants agreed with the number of maturity levels in the framework. However, one participant expressed that the description of maturity levels needed more specification. The participant recommended replacing 'Policy' with 'Standard practice' or 'Operating procedure'. The fifth question dealt with the responsiveness and applicability of the suggested framework with regard to construction organisations in India. All the participants stated that the framework was suitable for the current construction organisations in India. The researcher incorporated the recommendations from the interviews and

refined the framework accordingly. The revisions are highlighted in different colour in Table 4.28, demonstrating the refined OSC readiness framework for Indian construction organisations.

Table 4.28. Refined Off-Site Construction readiness framework

Factors	Level 1	Level 2	Level 3
	NO CLEAR APPLICATION	**FREQUENT APPLICATION. LACK OF STANDARD PRACTICE**	**ESTABLISHED OPERATING PROCEDURE**
	The organisation may / may not practice the critical steps for effective implementation of Off-site techniques. Organisations at this level need to re-visit their existing operations and re – structure their team to improve efficiency / readiness.	This level represents the frequency of application. At this level, the organisation significantly repeats a series of critical techniques. However, it will have scope for improvement in processes and need to define standard practice.	At this level, the organisation has clear standard practice about Off-Site Construction methods. It constantly reviews the existing operations and plans the project strategies to increase efficiency. The organisations at this level, document best procedures through recording experiences and lessons from the previous projects.
F1. Operational challenges			
F1. 1. Complex interfacing between the systems: How does the organisation respond to the challenges in assembling individual systems / products of a complex nature?	Is the workforce aware of the assembling techniques and interfacing of different products?	Does the organisation demonstrate how to assemble new, complex structures before erecting them on – site?	Does the organisation expedite the learning curve from one off-site project to another project, through integrating training programs in the strategy? Also, does the organisation prioritise capacity building in the policy?

F1.2. Duties and taxes: How does the organisation consider the leviability of duties and taxes on the Off-Site products.	Does the organisation identify the potential challenges associated with the duties and taxes on the Off-Site products?	Does the material procurement strategy of the organisation consider both imported and domestic Off-Site products? Also, does the organisation maintain any records to moniter the duties and taxes payable / already paid?	Does the organisation achieve optimal utilisation of imported and domestic products? Does it always prioritise the Off-Site products entitled with incentives or exemptions from the taxes?
F1.3. Level of experience in Off-Site construction: How many off-site projects have been handled? What is the level of expertise of the organisation?	Are the design and project development teams well aware of techniques and methods involved in off-site construction practices?	Do all the senior management, project teams, construction workforce have significant experience in handling off-site construction projects?	Does the organisation maintain a structure with dedicated project team and workforce that are specialised in off-site construction operations?
F1.4. Promoting advantages of Off-Site Construction techniques: How does the organisation handle the existing negative image (Goodier & Gibb, 2007; Arif. M *et. al.,* 2012) on off-site construction methods? Does it promote the advantages associated with OSC method.	Does the organisation promote the potential benefits from off-site construction methods? Also, does the organisation conduct any enlightenment programs / one to one sessions with the potential clients to clarify their concerns?	Does the organisation maintain a calendar of awareness workshops? Also, does it brief the potential clients about the nature of work, application methods and achievable benefits before starting the project?	Does the organisation extensively promote the benefits of OSC products by showcasing successful projects, value proposition and product samples? Also does it include the promotional activities in the strategy?

F1.5. Lead times: What is the capability of the organisation in avoiding delays caused by long lead times?	Does the organisation consult the manufacturers before planning all critical events in the project schedule?	Are all events planned according to the delivery schedules to avoid time lags between the commencement and completion of the project?	Does the organisation closely work with manufacturers and all the supply chain involved in the projects? Also, does it collaborate with manufacturers and facilitate an in-house set up for greater control on time schedules?
F1.6. Client's resistance and scepticism: How does the organisation address the resistance from clients?	Does the organisation explain to the client about the potential benefits of using OSC methods?	Does the organisation assure client about the added advantages with clear estimates and documentation along with detailed project plan?	Does the organisation involve client in key decision making process and clarify any concerns with clear evidence / past success stories? Also, does the organisation showcase successful projects and communicate the client about the progress of critical events with detail documentation?
F1.7. Guidance and information: To what extent, does the organisation support the field staff with guidance and information on off-site construction techniques?	Is the field workforce in the organisation provided with training, technical manuals and literature on new products? Also, is this accessible to the entire workforce?	Does the organisation arrange workshops and dedicated training from the manufacturers before implementing any new projects?	Does the organisation have dedicated resources (instructor, technical team, library, training room, facilities which enable audio- visual demonstration) for training and guidance in office and on site?

F2. Broad execution strategy			
F2.1. Transportation infrastructure: What are the plans and arrangements made by the organisation to address the problems raised due to the existing poor road and transportation network?	Is the organisation aware of the minimum requirements to transport materials used in off-site construction projects?	If yes, does it critically evaluate the existing road and transportation network and customise their procurement strategy accordingly?	Does the organisation co-ordinate with the manufacturers at the initial stage and document route plan and schedules before placing the order (or) before starting the project?
F2.2. Manufacturing facility: How does the organisation handle the volume of products and other resources required?	Does the organisation estimate the requirement / quantities and consult the manufacturing facility before starting construction?	If yes, does the organisation complete the selection process at the early stage and place orders with effective planning?	Does the organisation evaluate the capacity of manufacturers to meet demand? Also, does the organisation enter into agreements with supply contracts?
F2.3. Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported products with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers, to transfer and utilise their technology?
F2.4. Availability of codes / standards: The extent to which the organisation provide guidelines to the designers, operators and other construction workforce.	Are there any written standards/ guidelines available to all the members in project team?	Does the organisation strictly follow the standards throughout the design and construction stages?	Does the organisation document the instructions before design and monitor the activities to ensure compliance with the standards?

F2.5. Maximizing environmental performance in the life cycle: To examine the strategies deployed by the organisation to maximize the usage of sustainable products and processes in various projects.	Is the organisation aware of the off-site products that are sustainable? If yes, does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimising waste during construction, etc.) at the beginning of project?	Does the organisation establish a policy to use only certified or sustainable products recommended by standard organisations? Does the organisation also register for sustainable building certification?
F2.6. Capital cost: What is the financial preparedness of the organisation in terms of the capital investment?	Does the organisation allocate dedicated funds to support and accelerate the adoption of off-site construction techniques?	If yes, does the organisation maintain a financial strategy for future investments?	Does the organisation establish a policy on the investment diversification and strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?
F3. Certainty in planning			
F3.1. Cost certainty: To what extent does the organisation plan and monitor the budget performance?	Does the organisation document the estimates at the beginning of the project? Also, is there any evidence of integration between project administration and control?	If yes, does the organisation closely monitor the project expenses and compare with the estimates? Also, does it take measures to avoid any variation?	Does the organisation implement a standardised project financial accounting and management systems?

F3.2. Time certainty: How does the organisation plan the critical activities? What is the capability of the organisation to ensure that there is no variation between the estimated and actual completion date?	Does the organisation identify critical activities and follow their sequence of execution?	Does the organisation monitor and review on-site activities and take precautions to avoid any delay?	Does the organisation establish a policy to optimise performance through ensuring process standardisation?
F4. Operational efficiency			
F4.1. Minimising on-site duration: What is the capability of the organisation to reduce / minimise the duration of non-critical activities during construction on site?	Does the organisation identify and control / avoid the non-critical activities during planning and on site?	Does the organisation efficiently plan and execute all parallel activities during planning and on site?	Does the organisation ensure that all appropriate off-site activities are completed before starting erection on construction site? Also, does it standardise the on-site working process?
F4.2. Prompt delivery: How does the organisation ensure prompt delivery of products and services?	Does the organisation closely work with supply chain and logistics involved in various projects?	Does the organisation collaborate with select vendors and consultants involved in various projects?	Does the organisation maintain a directory of efficient vendors and service providers based on their performance? Is there a practice of partnering with providers / vendors?

4.13. Chapter Summary

This chapter has presented the descriptive data findings. The first section of the chapter discussed the application and results of the data collection tool - questionnaire survey. The researcher has conducted a questionnaire survey to explore the the nature and extent of current OSC practices in construction organisations in India. The findings from the literature review have directed to the content (types of OSC systems, drivers and barriers, and key factors towards successful implementation) of the questionnaire. The chapter also discussed about the piloting of the questionnaire and rationale of the selected tool. The survey attracted 218 professionals involved in the AEC projects. Amongst these participants, 140 have finished atleast one OSC project. The results revealed that 41.2 percent of the respondents were neutral about the current usage of OSC methods in India. On the other hand, only 3.9 percent gave excellent remark to the current practice of OSC in India. Interestingly, 43.1 percent of the respondents expressed that their organisations were considering to implement OSC in the near future. Currently, majority of the particiapnts (69.1 percent that is 141 respondents) are precasting some components and casting main structure on site. The results also revealed about the key influencing factors in India. 130 and 126 respondents have considered “minimising on-site duration” and “speedy delivery” as the most influencing factors towards the implementation of OSC in India. These results are in line with the finidings of the exisitng literature. This analysis has also found the drivers and barriers towards the adoption of OSC methods in India. Ensuring cost certainty (151 responses) and time certainty (130 responses) were marked as the top most driving factors. Similarly, risk averse culture (132 responses) and complex interfacing between the systems (128 responses) were identified as barriers to the uptake of OSC methods in India. The researcher has conducted factor analysis to identify and group the most prioritised factors in the case of India. This had provided a list of 17 variables in four groups. A conceptual readiness framework was constructed based on these variables. The researcher then refined the framework with help of semi-structured interviews. This chapter has discussed about the key stages involved in the development of OSC readiness framework, summary of interviews and refined framework. Finally the chapter presented the proposed OSC readiness framework. Thus the chapter achieved the objective two and three of the

research. The next chapter will discuss the testing and validation of the framework through case studies.

Chapter 5 | Validation of refined OSC Readiness Framework

This chapter presents the data analysis of the final stage. The researcher discussed the first two stages of data collection, development of the framework and the refinement process, in the previous data analysis chapter. The researcher conducted three case studies of the Indian construction organisations to evaluate the OSC readiness framework.

The proposed framework was validated within three construction organisations in India. This chapter portrays each case study individually and also discusses each factor within the organisations. The case study results will help the researcher in refining the framework according to the Indian context and industry requirements.

5.1. Case study guide

The researcher developed a case study guide (Table 5.1) to assess the identified factors of the proposed framework. This guide is divided into observable evidence and interview based evidence. The interview guide was designed to assess all the possible evidences against each factor and assign the maturity level under them. These evidences were identified through the accessible documentation of the organisation or through semi-structured interviews. In the process of a case study, the researcher interviewed senior project managers, architects, HR managers and technical staff of the selected organisations. All the participants possess more than three years of work experience in the field of OSC.

Table.5.1. Case study guide

Factor	***Level 1***	***Level 2***	***Level 3***
F1. Operational challenges			
F1.1. Complex interfacing between the systems	**Observable evidence:** This can be assessed by looking at the working style / skill of the workforce in	**Observable evidence:** This can be obtained by looking at the organisation's demonstrations (figures showing	**Observable evidence:** This can be checked by looking at the graphical charts (explaining the sequence of assembling OSC

Factor	*Level 1*	*Level 2*	*Level 3*
	dealing with complex systems / systems in OSC. **Interview based evidence:** By asking the senior management, if the workforce is aware of the assembling techniques of various complex systems used in OSC. Also, by asking how they addressed the challenges during assembling any new Off-site systems.	the sequence of assembling OSC systems) and OSC training records if any. **Interview based evidence:** By asking some individuals in the workforce, about the training on OSC methods, and facilities they have been availed. Also, asking if they contact any technical staff for guidance if they find difficulties in assembling the OSC systems.	systems / systems), if any in the office premises and construction site. If possible, this evidence can also be taken by checking for special training on OSC methods in the training register. **Interview based evidence:** By asking the senior management, if they prioritise staff capacity building and include it in the policy.
F1.2. Duties and taxes	**Observable evidence:** **Interview based evidence:** By asking the senior management, if they learnt about potential duties and taxes on OSC systems, before purchase.	**Observable evidence:** **Interview based evidence:** By asking the senior management, if they considered all the applicable duties and taxes on the systems used in OSC projects, before purchase. Also, if the organisation avoided duties by installing more	**Observable evidence:** **Interview based evidence:** By asking the senior managers about their decision making policy about the systems. Also, the consumption of systems with exemptions and incentives.

Factor	*Level 1*	*Level 2*	*Level 3*
		locally manufactured OSC systems. By asking the senior management if they considered the incidence of duties and taxes on OSC systems before purchase.	
F1.3. Level of experience in Off-Site Construction methods	**Observable evidence:** If possible, by looking at the skills profile of the design, and project development teams, to note their experience in OSC projects. **Interview based evidence:** By asking the senior management in the design and project development if they are conversant with the techniques and methods of Off-Site Construction.	**Observable evidence:** If possible, by looking at the skills profile of the design, and project development team, to note their experience in OSC projects. **Interview based evidence:** By asking the senior management about their experience and knowledge in the Off-Site Construction methods. Also, by asking the construction workforce on-site about their experience in working in OSC projects.	**Observable evidence:** If possible, by looking at the organisation's experience in completing OSC projects. **Interview based evidence:** By asking the senior management if they maintain a dedicated team specialised in OSC projects. Also, by asking if the organisation recruits skilled workforce for Off-Site Construction projects.

Factor	*Level 1*	*Level 2*	*Level 3*
F1.4. Promoting advantages of Off-Site construction techniques	**Observable evidence:** If possible, by looking at the records with details of the OSC themed awareness programs conducted by the organisation. **Interview based evidence:** By asking the senior management, if they have conducted any enlightenment programs to promote Off-Site Construction methods.	**Observable evidence:** If possible, by looking at the records and event calendars of the organisation to notice if there are any events conducted on the concept of OSC. **Interview based evidence:** By interviewing senior management about the approach of organisation in promoting Off-Site Construction methods. Also, by asking about their participation in exhibitions and seminars in the area of OSC.	**Observable evidence:** If possible, by looking at the records and event calendars of the organisation, to identify programs with OSC theme. Also, observing display of previous success stories of OSC projects and literature about benefits from Off-Site Construction, in the visitors lounge (or) in other premises of office, if any. **Interview based evidence:** By asking the senior management about their strategy on promoting OSC methods. Also, if the organisation have participated in exhibitions /lectures / seminars to portray their successful OSC projects.

Factor	*Level 1*	*Level 2*	*Level 3*
F1.5. Lead times	**Observable evidence:** **Interview based evidence:** By asking one of the senior management, if they consulted the manufacturers of OSC systems about the time frames before preparing the project work schedules.	**Observable evidence:** **Interview based evidence:** By asking the senior management, if they always adhered to OSC systems delivery schedules in project planning and ensured no time lags between the commencement and completion of the project.	**Observable evidence:** By checking if the organisation collaborated with any manufacturers of OSC systems. Also, if the organisation maintains an in-house facility to manufacture OSC systems. If possible, by looking at the strategy of the organisation, in terms of OSC. **Interview based evidence:** By asking one of the senior management, if the organisation collaborated with any manufacturers of OSC systems. If yes, by asking about the scope of collaboration. Also, if the organisation already maintains an in-house manufacturing capacity (or) is planning for an in-house facility to produce OSC systems.
F1.6. Client resistance and scepticism	**Observable evidence:** This can be assessed by examining the client meeting records, to notice the minutes about OSC, if possible.	**Observable evidence:** If possible, by looking at the documentation provided to the client about the OSC methods, and meeting records	**Observable evidence:** If possible, by looking at the documentation provided to the client about the OSC methods, meeting records,

Factor	*Level 1*	*Level 2*	*Level 3*
		with details about OSC.	and publicity material with data on OSC.
	Interview based evidence: By asking the design team, if they explain about the potential benefits of using OSC methods, to the client.	**Interview based evidence:** By asking the senior management, if they provide clear estimates, and time schedules with a detail project plan to the clients. Also, how they address complaints in the OSC projects, if any.	**Interview based evidence:** By asking one of the senior management, about their policy on OSC project briefing. If they involve client in key decision making process and clarify any concerns about OSC techniques with clear evidence. Also, by asking if they share experiences of the previous successful OSC projects, with other clients.
F1.7. Guidance and information	**Observable evidence:** By checking the technical manuals / literature about OSC methods, which are available for the workforce, if possible.	**Observable evidence:** By checking the technical manuals / literature on OSC methods and OSC systems, in the office / on site. Also, if possible, by checking the training and workshop registers, announcements and other staff communication, to identify the attention paid to OSC methods.	**Observable evidence:** By checking the technical manuals / literature available. Also, if possible, by checking the trainings and workshop registers, announcements and other staff communication. By visiting the resource room and training facilities.
	Interview based evidence: By asking one of the senior management, if	**Interview based evidence:** By asking the senior management, if	**Interview based evidence:** By asking the senior management, if the organisation has

Factor	*Level 1*	*Level 2*	*Level 3*
	they provide any training on working procedures in OSC. Also asking if the technical manuals and literature about the new OSC systems are accessible for the workforce.	they conducted workshops before installation of new OSC systems. If the organisation maintained library with technical manuals and other required literature on OSC. Also, if the organisation provided constant support to the workforce during construction (through appointing instructors on-site, and placing instructions and signposts on application of OSC systems)	dedicated resources focusing on OSC (instructors, technical support team, training room, library etc.). Also, if they allocate funds exclusively for guidance purpose. If possible, by questioning the instructor (or) a member of support team about the scope and nature of training and support provided for the staff working in the OSC projects.
F2. Broad execution strategy			
F2.1. Transportation infrastructure	**Observable evidence:** If possible, by accessing the transport planning drawings used in OSC projects, if any. **Interview based evidence:** By asking the senior management, if they are aware of prerequisites for transporting systems used in the OSC projects.	**Observable evidence:** If possible, by accessing the transportation planning records, used in OSC projects if any. **Interview based evidence:** By asking the senior management, if they critically evaluated the existing road network and customised their procurement strategy accordingly, for the OSC projects.	**Observable evidence:** If possible, by accessing the transportation planning records implemented in OSC projects. **Interview based evidence:** By asking the senior management, if they co-ordinated with the manufacturers of OSC systems and produced appraisal documents on existing transportation facilities, at the

Factor	*Level 1*	*Level 2*	*Level 3*
			early stage (before planning).
F2.2. Manufacturing capacity	**Observable evidence:** If possible, by looking at the bill of quantities, purchase orders and receipts of the procured OSC systems. **Interview based evidence:** By asking the senior management, if they estimated the quantities of materials and consulted the OSC systems manufacturing facility before starting OSC projects.	**Observable evidence:** If possible, by looking at the bill of quantities, purchase orders and receipts of the procured OSC systems. **Interview based evidence:** By asking the senior management if they completed the selection of OSC systems at the early stage and effectively planned the purchase and delivery.	**Observable evidence:** If possible, by looking at the appraisal document on the OSC systems manufacturing capacity, and agreements with manufacturing companies producing OS systems. **Interview based evidence:** By asking the senior management, if they evaluated the potential of manufacturing company to deliver the required number of OSC systems, before purchase. Also, if they signed any agreement with the OSC systems manufacturing companies.
F2.3. Shortage in local availability	**Observable evidence:** **Interview based evidence:** By asking the senior management, how	**Observable evidence:** **Interview based evidence:** By asking the senior management, how	**Observable evidence:** By looking at the in-house OSC system manufacturing facility maintained by the organisation, if any. **Interview based evidence:** By asking the senior

Factor	*Level 1*	*Level 2*	*Level 3*
	they addressed the problems encountered due to the shortage of locally manufactured OSC systems.	imported OSC systems were utilised to complement the locally manufactured OSC systems.	management, if the organisation collaborated with foreign OSC systems manufacturers to address the shortage of local OSC systems. Also, by asking if there is any effective in-house facility maintained by the organisation to manufacture OSC systems.
F2.4. Availability of codes / standards	**Observable evidence:** By looking at the literature on OSC standards that is available for the staff. Also, if possible, by looking at the design drawings of OSC projects. **Interview based evidence:** By asking the senior management, if they obtained standards on OSC system usage before starting design? Also, if they observed design codes in the whole OSC project.	**Observable evidence:** By looking at the literature on OSC standards that is available for the staff. Also, if possible, by looking at the design drawings, execution review and quality reports of OSC projects. **Interview based evidence:** By asking the senior management, if they strictly comply with OSC standards in the design and execution in the OSC projects.	**Observable evidence:** By looking at the literature on OSC standards that is available for the staff. Also, if possible, by looking at the instruction documents, design drawings, execution review and quality reports of OSC projects. **Interview based evidence:** By asking the senior management, if the organisation monitors and reviews the construction activities to ensure compliance with standards of OSC systems.
F2.5. Maximising environmental	**Observable evidence:**	**Observable evidence:**	**Observable evidence:**

Factor	*Level 1*	*Level 2*	*Level 3*
performance in the life cycle	By looking at the range of systems used in various OSC projects. Also, if possible, by looking at the project brief, to notice the importance given to environmental performance. **Interview based evidence:** By asking the senior management, if they are aware of sustainable off-site systems? Also, if they used such systems before, in the OSC projects.	By looking at the range of systems used in various OSC projects. Also, if possible, by looking at the project brief, to examine the approach to environmental performance. **Interview based evidence:** By asking the senior management, if they adopted sustainable practices (by selecting sustainable OSC systems, minimizing waste during construction, and maintaining less disruptions and pollution during construction etc.).	If possible, by looking at the organisation policy and individual project documents, to assess the approach towards environmental performance. **Interview based evidence:** By asking the senior management, if they maintain a policy to use only certified sustainable systems in the OSC projects. Also, if the organisation pre-register or apply for sustainability certification.
F2.6. Capital cost	**Observable evidence:** **Interview based evidence:** By asking the senior management, if the organisation allocated funds to accelerate the adoption of off-site construction methods.	**Observable evidence:** **Interview based evidence:** By asking the senior management, if they reviewed financial plan for future investments in OSC domain.	**Observable evidence:** **Interview based evidence:** By asking the senior management, if the organisation diversifies its investment in areas related to OSC. Also, if there are any investment appraisal reports, focusing on OSC.

Factor	*Level 1*	*Level 2*	*Level 3*
F3. Certainty in planning			
F3.1. Cost certainty	**Observable evidence:** If possible, by looking at the cost estimate, and project brief documents of OSC projects. **Interview based evidence:** By asking the senior management, if they documented the cost estimation at the beginning of the OSC project; and if the organisation practiced cost control.	**Observable evidence:** If possible, by looking at the cost estimate, and project brief and completion documents of OSC projects. **Interview based evidence:** By asking the senior management, if they have a practice of monitoring OSC project expenses and comparing with the estimates. Also, if the organisation has been taking measures to avoid variation, if any.	**Observable evidence:** If possible, by looking at the standardised policy of the organisation, in terms of OSC. **Interview based evidence:** By asking the senior management, if they maintain a standardised project financial accounting and management system designed for OSC projects.
F3.2. Time certainty	**Observable evidence:** If possible, by looking at the OSC project work plan, review documents during construction and completion reports. **Interview based evidence:** By asking the senior management, if they identified critical activities involved in OSC projects at the early stage and planned them	**Observable evidence:** If possible, by looking at the OSC project work plan, construction progress documents, and completion reports. **Interview based evidence:** By asking the senior management, if they followed the work plan in the required sequence during execution of OSC activities. Also, if they	**Observable evidence:** If possible, by looking at the policy document articulated for OSC projects and completion reports of OSC projects. **Interview based evidence:** By asking the senior management, if they maintain a policy to optimise performance in OSC projects? Also, if they have process

Factor	*Level 1*	*Level 2*	*Level 3*
	accordingly.	monitored and reviewed the on-site activities to avoid any delay.	standardisation customised for OSC projects.
F4. Operational efficiency			
F4.1. Minimising on-site duration	**Observable evidence:** If possible, by looking at the project work plan and activity review documents of OSC projects. **Interview based evidence:** By asking the senior management, if they identify and avoid the non – critical activities during planning of OSC projects.	**Observable evidence:** If possible, by looking at the project work plan and activity review documents of OSC projects. **Interview based evidence:** By asking the senior management, how they plan and execute all parallel activities in OSC projects.	**Observable evidence:** If possible, visiting one or more OSC sites, and notice if there is process standardisation. **Interview based evidence:** By asking the senior management, if they maintain a policy on process standardisation for all OSC projects. Also, if the organisation completes all off-site activities away from site.
F4.2. Prompt delivery	**Observable evidence:** If possible, by looking at the dates of purchase orders and delivery documents of all OSC systems. **Interview based evidence:** By asking the senior management, if they closely worked with the supply chain (i.e. repeating any	**Observable evidence:** If possible, by looking at the dates of purchase orders and delivery documents of all OSC systems. **Interview based evidence:** By asking the senior management, if they have collaboration with selected vendors and consultants involved in various	**Observable evidence:** If possible, by looking at the directory of approved vendors and service providers to be used in OSC projects. **Interview based evidence:** By asking the senior management, if they maintain a directory of approved vendors

Factor	*Level 1*	*Level 2*	*Level 3*
	vendors) in the OSC projects.	OSC projects.	and service providers based on their performance in OSC projects. Also, if the organisation award OSC projects to new vendors based on critical appraisal.

For the case studies, the researcher approached several construction organisations that are practicing off-site construction methods. In the process, three organisations have agreed to participate in the research. All the participants were selected based on their position and experience in the field of OSC projects. In the first step, the researcher provided information about the research and explained the purpose of these case studies to all the participants. Furthermore, all the participants were interviewed about the level of maturity of each key factor and sub-factor in their organisations.

5.2. Case study 1

5.2.1. Background of the organisation

Table 5.2 Profile of the Organisation A

Year of establishment	1982
Areas of specialisation	Engineering, design, construction and procurement for urban infra, industrial infra, Ports and terminals, roads, bridges and metros
Location	Visakhapatnam, Hyderabad, Bengaluru, New Delhi, and Nagpur

5.2.2. Evaluation of OSC readiness of organisation A

Factor 1. Operational challenges

Factor 1.1. Complex interfacing between the systems

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1. 1. Complex interfacing between the systems: How does the organisation respond to the challenges in assembling individual systems / products of a complex nature?	Is the workforce aware of the assembling techniques and interfacing of different products?	Does the organisation demonstrate how to assemble new, complex structures before implementing them on – site?	Does the organisation expedite the learning curve from one off-site project to another project, through integrating training programs in the strategy? Also, does the organisation prioritise capacity building in the policy?

In the interview, the project manager stated that, *"(The) majority of the construction operations are complex and costly. Working in (the) off-Site style of construction is highly complex. The organisation understood this and made several attempts to address this."* According to the participants, the organisation prioritises staff training. There is a standard practice of providing training to every new employee in the first month of their job. In addition to this, the management conducts staff training in their in-house learning academy before initiating on-site works in every project. The field supervisor mentioned that a technical instructor was appointed in the previous project in order to assist the workforce in working with new and complex systems. All the on-site workers were provided with demonstration and one

to one sessions on assembling techniques. Though the organisation has an established policy on training, they did not customise a standard procedure for OSC projects. Therefore, the organisation achieved level two in terms of "complex interfacing between the systems" in the OSC readiness framework.

Factor 1.2. Duties and taxes

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.2. Duties and taxes: How does the organisation consider the leviability of duties and taxes on the Off-Site products?	Does the organisation identify the potential challenges associated with the duties and taxes on the Off-Site products?	Does the material procurement strategy of the organisation consider both imported and domestic Off-Site products? Also, does the organisation maintain any records to monitor the duties and taxes payable / already paid?	Does the organisation achieve optimal utilisation of imported and domestic products? Does it always prioritise the Off-Site products entitled with incentives or exemptions from the taxes?

The organisation predominantly uses locally available material and systems, and the management instructed the design and procurement teams to purchase all the material from local vendors. The project manager indicated that the finance division deals with all the purchase orders and finances of every project. He stated, *"There were incidents where some vendors submitted bills at the site office. But, the management gave us strict instructions to hand over those bills to the finance department. So, we rarely know the details about the taxes"*. On the other hand, one senior project manager said that the finance department maintains the records of the paid and payable taxes. Based on this, the researcher assigned level two to Organisation B against the factor "Duties and Taxes".

Factor 1.3. Level of experience in off-site construction methods

Factor	*Level 1*	*Level 2*	*Level 3*
F1. Operational challenges			
F1.3. Level of experience in Off-Site construction: How many off-site projects have been handled? What is the level of expertise of the organisation?	Are the design and project development teams well aware of techniques and methods involved in off-site construction practices?	Do all the senior management, project teams, construction workforce have significant experience in handling off-site construction projects?	Does the organisation maintain a structure with dedicated project team, and workforce that are specialised in off-site construction operations?

The researcher had an opportunity to interview the HR manager of the organisation. The manager reported that five of their current employees have more than seven years of experience in working in the OSC area. The researcher could not access the staff details and records; however, according to the HR manager, three of their project managers have worked on two OSC projects. She also indicated that the management is keen to recruit OSC experienced employees and skilled work force in the near future. The organisation has a strategic approach towards recruitment. In her words, *"Our organisation recruits high number of diploma graduates and ITI students. They join us for apprenticeships and they continue to work with us. We train them according to our needs and assign projects accordingly"*. The above comment illustrates that the majority of the employees are trained to be professional rather than technically/academically qualified. However, as the manager stated, the management is re-visiting this approach and aiming to balance the teams with experienced employees and new graduates. The researcher assessed the present state of the organisation and assigned level one to the factor "Level of Experience in Off-Site Construction Methods" in the OSC readiness framework.

Factor 1.4. Promoting advantages of off-site construction techniques

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.4. Promoting advantages of Off-Site construction techniques: How does the organisation handle the existing negative image (Goodier & Gibb, 2007; Arif. M *et. al.,* 2012) on off-site construction methods? Does it promote the advantages associated with OSC method?	Does the organisation promote the potential benefits from off-site construction methods? Also, does the organisation conduct any enlightenment programs / one to one sessions with the potential clients to clarify their concerns?	Does the organisation maintain a calendar of awareness workshops? Also, does it brief the potential clients about the nature of work, application methods and achievable benefits before starting the project?	Does the organisation extensively promote the benefits of OSC products by showcasing successful projects, value proposition and product samples? Also does it include these promotional activities in the strategy?

The organisation prioritised promotional activities in their strategy. According to the participants, the organisation extensively participates in the annual exhibitions. It also established relations with three government institutes in Visakhapatnam and Hyderabad. The management conducts awareness programmes and lecturing sessions in the college of architecture. The organisation maintains a calendar of academic and awareness programmes. In addition, some of the staff write articles in the local newspapers about various advancements in the construction industry. The researcher noticed success stories, details of land mark projects and award winning projects in the official website of the organisation. From the above, it can be understood that the organisation achieved level three in terms of "Promoting Advantages of Off-Site construction Techniques".

Factor 1.5. Lead times

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.5. Lead times: What is the capability of the organisation in avoiding delays caused by long lead times?	Does the organisation consult the manufacturers before planning all critical events in the project schedule?	Are all events always planned according to the delivery schedules, to avoid time lags between the commencement and completion of the project?	Does the organisation closely work with manufacturers and all the supply chain involved in the projects? Also, does it collaborate with manufacturers and facilitate an in-house set up for greater control on time schedules?

The researcher received opinions from two senior project managers, one project co-ordinator, one block supervisor and one project manager on this factor. One of the senior project managers explained about the in-house manufacturing facility of the organisation. The organisation runs a fully equipped fabrication yard of 20,000 square meters in Visakhapatnam, Andhra Pradesh. In addition to this, it maintains good relations with various stakeholders. For example, they are currently constructing three metro stations in three cities in India. Despite the difference in locations, they are achieving positive results in terms of quality and time. The project co-ordinator stated, *"We always believe in mutual respect and trust and collaborative openness. The entire supply chain of our projects has high regards for our organisation"*.

The senior project manager explained that the design and engineering teams always work closely with the manufacturers and schedule the activities accordingly. In addition, the procurement team tracks the supply chain and delivery schedules. The in-house facility offers additional support. Thus the organisation ensures no delays to the activities on the critical path. Therefore, the organisation is at level three in the "lead times" area of the OSC readiness framework.

Factor 1.6. Client's resistance and scepticism

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.6. Client's resistance and scepticism: How does the organisation address the resistance from clients?	Does the organisation explain to the client about the potential benefits of using OSC methods?	Does the organisation assure client about the added advantages with clear estimates and documentation along with detailed project plan?	Does the organisation involve client in key decision making process and clarify any concerns with clear evidence / past success stories? Also, does the organisation showcase successful projects and communicate the client about the progress of critical events with detail documentation?

All the participants expressed that there was significant resistance from some of the clients. However, they observed that this has reduced in recent years. According to the participants, the organisation religiously encourages all their clients to achieve excellence and competitive advantage through adopting modern methods of construction. The strategy of the organisation emphasises innovation and application of modern methods in construction and infrastructure development. The organisation is driven by the belief that innovative thinking prevails. Hence, the design and engineering team motivates potential clients to adopt modern methods of construction. Furthermore, the consultancy team offers counselling to the clients to clarify their concerns regarding these new methods of construction. A project manager shared his experience of taking one of the potential clients to the on-going OSC project to demonstrate the working methods live. According to the manager, the project team also showed some schedules and progress of the project to the client.

On the other hand, the architects shared different experiences from their design brief meetings. According to them, some of the clients have approached with a decision to partially implement OSC methods to complete their projects on-time. From the interviews, the researcher noticed that the organisation encourages all their clients to adopt OSC methods based on the relevancy of the projects. Therefore, it can be said that the organisation reached level two of the OSC readiness in terms of **"**Client's Resistance and Scepticism".

Factor 1.7. Guidance and information

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.7. Guidance and information: To what extent, does the organisation support the field staff with guidance and information on Off-Site construction techniques?	Is the field workforce in the organisation provided with training, technical manuals and literature on new products? Also, is this accessible to the entire workforce?	Does the organisation arrange workshops and dedicated training from the manufacturers before implementing any new products?	Does the organisation have dedicated resources (instructor, technical team, library, training room, facilities which enable audio-visual demonstration) for training and guidance in office and on site?

According to the project manager, the management ensures that all the learning material and guidance charts are displayed in the site office. The organisation established a learning practice for all the projects. In this procedure, an instructor from the learning academy (the researcher discussed this academy in factor 1.1.) or from the manufacturers (whoever is relevant) trains the supervisors and team leaders of various field staff. The team leaders then train the respective workforce. In addition to this, the management also conducts weekly training session on the site. The instructors and technical staff ensure that the entire workforce is well aware of the working methods and installation procedure. The project manager shared his experience from the previous project, describing how the workforce had to install

toilet pods in one of the cargo village facility projects. In the first week, the instructor from the manufacturers trained all the team members on installation. Furthermore, the instructor also made the team to erect a mock –up of the same. Beyond this, the instructor corrected the procedure done by some of the team members and also clarified their doubts. Thus, the exercise ensured that the installation method reached across the workforce in an equal and effective manner. From the above interview and example, it can be concluded that the organisation achieved level three in terms of readiness in adopting OSC methods.

F2. Broad Execution strategy

F2.1. Transportation infrastructure

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.1. Transportation infrastructure: What are the plans and arrangements made by the organisation to address the problems raised due to the existing poor road and transportation network?	Is the organisation aware of the minimum requirements to transport materials used in off-site construction projects?	If yes, does it critically evaluate the existing road and transportation network and customise their procurement strategy accordingly?	Does the organisation co-ordinate with the manufacturers at the initial stage and document route plan and schedules before placing the order (or) before starting the project?

The senior project manager conveyed that the management is well aware of the pre-requisites involved in the transportation of OSC products. As the project manager mentioned earlier, the organisation extensively builds with local products. In addition, the organisation runs an in-house fabrication yard (this was discussed in factor F1.5). So, the majority of the material is procured from this in-house facility or from local vendors. The project manager shared that the procurement team schedules the delivery of material only in the night time. In addition, the procurement team also documents the traffic guidelines of the recipient's city/area.

In India, the majority of the cities allow heavy vehicles only after the peak hours, therefore, the project logistics team plans the transportation and delivery according to the rules. Based on these findings, the researcher assigned level two to the organisation in terms of “Transportation Infrastructure”.

F2.2. Manufacturing capacity

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.2. Manufacturing capacity: How does the organisation handle the volume of products and other resources required?	Does the organisation estimate the requirement / quantities and consult the manufacturing facility before starting construction?	If yes, does the organisation complete the selection process at the early stage and place orders with effective planning?	Does the organisation evaluate the capacity of manufacturers to meet demand? Also, does the organisation enter into binding supply contracts?

The project design and engineering team explained that they finalise the product selection and prepare all the estimation documents at the early stages of the project. The procurement and logistics team prepares a critical evaluation report of the potential manufacturers and vendors. The organisation is equipped with an in-house fabrication yard. In addition, the management awards the contracts based on the appraisal report and performance of the manufacturers. The project manager also shared that, in the last six years, the management has repeatedly awarded contracts to four vendors based on their effective and prompt delivery. Therefore, level three is assigned to the organisation in terms of “Manufacturing Facility”.

F2.3. Shortage in availability

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.3. Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported products with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers, to transfer and utilise their technology?

In the interview, all the participants expressed how shortage of materials and services is challenging the performance of the organisation. According to the senior project manager, the organisation's fabrication yard is manufacturing round the clock to meet the requirements. Despite the continuous efforts from the in-house facility and other associated manufacturers, the projects suffer from late delivery in some cases. This is contrary to the statements given during the assessment of "lead times". This could be because the interviewee was asked about the shortage of availability in particular, and participants remembered previous experiences from other projects. From the interview findings, it can be concluded that the current organisation comprises an in-house facility. Despite this, the shortage of availability of products and technology is threatening the efficiency and performance of the organisation. Therefore, the organisation can be assigned with level one for this factor.

F2.4. Availability of codes/standards

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.4. Availability of codes /	Are there any written standards/	Does the organisation	Does the organisation

standards: The extent to which the organisation provide guidelines to the designers, operators and other construction workforce.	guidelines available for all the members in project team?	strictly follow the standards throughout the design and construction stages?	document the instructions before design, and monitor the activities to ensure compliance with the standards?

As mentioned earlier, the organisation procuress majoritvely locally manufactured products. In the in-house facility they ensure that all products are manufactured as per the standards. In addition, they also provide the user a manual for all the products. The architects stated that they receive standards and guidelines for a significant number of products. They strictly follow the guidelines during the design and execution stages. Furthermore, the project planning and quality control team closely monitor the execution process to ensure that the entire workforce meets the standards. From the interview findings, it can be concluded that the organisation achieved level three of readiness in this factor.

F2.5. Maximising environmental performance in the life cycle

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.5. Maximising environmental performance in the life cycle: To examine the strategies deployed by the organisation to maximise the usage of sustainable products and processes in various projects.	Is the organisation aware of the off-site products that are sustainable? If yes, does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimising waste during construction, to name a few) at the beginning of project?	Does the organisation establish a policy to use only certified or recommended products by the sustainable organisations? Does the organisation also register for sustainable building certification?

All the participants stated that they are aware of the off-site products with eco-friendly features. However, they collectively expressed that the management does not prioritise the usage of these products. The senior architects commented, *"These days everyone is tagging eco – friendly - Green etc to several products, but a, majority of the manufacturers of these products lack a holistic approach towards sustainability"*. According to this participant, client's choice is the deciding factor in the application of sustainable off-site products. From the interviews, it appears the organisation reached only level one in the area of "Maximising Environmental Performance in the Lifecycle".

F2.6. Capital Cost

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F2. Broad execution strategy			
F2.6. Capital cost: What is the financial preparedness of the organisation in terms of the capital investment?	Does the organisation allocate dedicated funds to support and accelerate the adoption of off-site construction techniques?	If yes, does the organisation maintain a financial strategy for future investments?	Does the organisation establish a policy on the investment diversification and strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?

The senior project manager conveyed that the organisation is committed to enhancing the learning curve of the current workforce. He also mentioned that the management is committed to the advancement of current practices. On the other hand, a majority of the participants were unaware about the capital investment and financial planning of the organisation. One of the interviewees expressed that the organisation had invested in the most-modern construction and allied equipment that enabled the workforce to successfully address the wide range of challenges. The researcher also noticed that the organisation allocates dedicated financial sources for the successful adoption of modern methods in construction. According to the

findings, it can be understood that the organisation is at level one in terms of the "Capital Cost" factor.

F3. Certainty in planning

F3.1. Cost certainty

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F3. Certainty in planning			
F3.1. Cost certainty: To what extent, does the organisation plan and monitor the budget performance?	Does the organisation document the estimates at the beginning of the project? Also, is there any evidence of integration between project administration and control?	If yes, does the organisation closely monitor the project expenses and compare with the estimates? Also, does it take measures to avoid any variation?	Does the organisation implement a standardised project financial accounting and management systems?

The participants from the interviews expressed that cost was prioritised in all the projects. The organisation emphasises cost effectiveness and adding a competitive advantage to all their clients. The quantity surveyors team and procurement team prepare the estimation and delivery schedules. The finance department also closely monitors the actual project cost and compares this with the estimation. Based on the findings, the researcher assigned level two to this factor.

F3.2. Time certainty

Factor	**Level 1**	**Level 2**	**Level 3**
F3. Certainty in planning			
F3.2. Time certainty: How does the organisation plan the critical activities? What is the capability of the organisation to	Does the organisation identify critical activities and follow their sequence of execution?	Does the organisation monitor and review the process and take precautions to avoid any delay?	Does the organisation establish a policy to optimise performance through ensuring process standardisation?

ensure that there is no variation between the estimated and actual completion date?			

The senior project manager conveyed that the project planning team of the organisation had effective co-ordination with the manufacturers and all other stakeholders of any project. The management ensures critical planning of all projects. The procurement and supply chain department works on purchase orders, delivery schedules and the status of the material. As discussed in the findings of F1.5. the organisation maintains an in-house fabrication yard. This enables prompt delivery of products to site on time. However, the organisation has yet to customise a standard procedure for OSC projects. Therefore, it can be concluded that the organisation achieved level two in terms of "Time Certainty".

F4. Operational efficiency

F4.1. Minimising on-site duration

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F4. Operational efficiency			
F4.1. Minimising on-site duration: What is the capability of the organisation to reduce / minimise the duration of non-critical activities during construction on site?	Does the organisation identify and control / avoid the non-critical activities during planning and on site?	Does the organisation efficiently plan and execute all parallel activities during planning and on site?	Does the organisation ensure that all appropriate off-site activities are completed before starting erection on construction site? Also, does it standardise the on-site working process?

The project management team monitors the on-site construction activities. The participants shared that the project manager and the site in charge organise weekly meetings from the inception till the handover stage. The chief project manager

reviews the progress of the project in these meetings, and the team responds to the review report and addresses any challenges in terms of time and quality. The senior project manager stated that the management established this standard procedure to focus on all areas of project management. However, this practice is not customised for OSC projects. Based on the findings, the researcher assigned level two against the OSC readiness of the organisation in the area of "Minimising On-Site Duration".

F4.2. Prompt delivery

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F4. Operational efficiency			
F4.2. Prompt delivery: How does the organisation ensure prompt delivery of products and services?	Does the organisation closely work with supply chain and logistics involved in various projects?	Does the organisation collaborate with selected vendors and consultants involved in various projects?	Does the organisation maintain a directory of efficient vendors and service providers based on their performance? Is there a practice of partnering with providers / vendors?

The organisation has an in-house fabrication yard. This ensures prompt delivery of self-manufactured systems to the selected projects. In addition, the organisation also maintains collaborations with the supply chain and service providers. The participants explained that the procurement team develops an appraisal report of potential vendors and service providers. This report presents the critical evaluation of the vendors in terms of eligibility, experience, resources and infrastructure capacity. The management awards projects based on the evaluation. Therefore, level three is assigned against this factor.

Table 5.3. Summary of results of Organisation A

Factor	**OSC Readiness level of Org. A**
F1. Operational challenges	
F1.1. Complex interfacing between the systems	Level - 2
F1.2. Duties and taxes	Level - 2
F1.3. Level of experience in Off-Site Construction methods	Level - 1
F1.4. Promoting advantages of Off-Site construction techniques	Level – 3
F1.5. Lead times	Level – 3
F1.6. Client resistance and scepticism	Level – 2
F1.7. Guidance and information	Level – 3
F2. Broad execution strategy	
F2.1. Transportation infrastructure	Level – 2
F2.2. Manufacturing capacity	Level – 3
F2.3. Shortage in local availability	Level – 1
F2.4. Availability of codes / standards	Level –3
F2.5. Maximising environmental performance in the life cycle	Level - 1
F2.6. Capital cost	Level - 1
F3. Certainty in planning	
F3.1. Cost certainty	Level - 2
F3.2. Time certainty	Level - 2
F4. Operational efficiency	
F4.1. Minimising on-site duration	Level - 2
F4.2. Prompt delivery	Level - 3

5.3. Case study 2

5.3.1. Background of the organisation

Organisation B was founded in 1938. It is considered one of the largest engineering and construction companies in India. Their area of work includes construction, heavy equipment, electrical equipment, power, and shipbuilding. Further details about the organisation are shown in the Table 5.4.

Table 5.4. Profile of the Organisation B

Year of establishment	1938
Areas of specialisation	Construction- (building & factories, transportation infrastructure, heavy civil infrastructure), heavy equipment, electrical equipment, power, and shipbuilding
Number of employees	84,027
Location	Mumbai – India (other locations include Middle East, East Asia, and South East Asia).

5.3.2. Evaluation of OSC readiness of organisation B

The data collected through interviews and observations will be assessed against the key factors and sub – factors of the readiness framework before being discussed in detail in this section. The researcher also visited one of the ongoing projects being executed by the organisation. This site is located in Hyderabad. The researcher collected observable evidences from this site visit.

Factor 1. Operational challenges

Factor 1.1. Complex interfacing between the systems

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice.**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1. 1. Complex interfacing between the systems: How does the organisation respond to the challenges in assembling individual systems / products of a	Is the workforce aware of the assembling techniques and interfacing of different products?	Does the organisation demonstrate how to assemble new, complex structures before implementing them on – site?	Does the organisation expedite the learning curve from one off-site project to another project, through integrating training programs in the strategy? Also, does the

Factor	*Level 1* No clear application	*Level 2* Frequent application. Lack of standard practice.	*Level 3* Established operating procedure.
complex nature?			organisation prioritise capacity building in the policy?

The organisation has established a practice of conducting training sessions and workshops on site before executing the usage of OSC products. According to the senior manager, the organisation recruited a skilled workforce to work on their current projects where a higher number of OSC products are being used. During the site visit, the researcher observed the posters explaining the sequence of installation and safety measures on the walls of the site office. Hence, the organisation is at the third level in terms of OSC readiness towards the factor "Complex interfacing between the systems". The organisation is committed to providing training and education on the application and complex nature of the OSC products. This will result in the successful adoption of OSC methods in their projects.

Factor 1.2. Duties and taxes

Factor	*Level 1* No clear application	*Level 2* Frequent application. Lack of standard practice.	*Level 3* Established operating procedure.
F1. Operational challenges			
F1.2. Duties and taxes: How does the organisation consider the leviability of duties and taxes on the Off-Site products?	Does the organisation identify the potential challenges associated with the duties and taxes on the Off-Site products?	Does the material procurement strategy of the organisation consider both imported and domestic Off-Site products? Also, does the organisation maintain any records to monitor the duties and taxes payable / already paid?	Does the organisation achieve optimal utilisation of imported and domestic products? Does it always prioritise the Off-Site products entitled with incentives or exemptions from the taxes?

According to the participants, i.e. the senior manager and assistant project manager, the organisation usually considers the incurring duties and taxes on the OSC products and general services during the procurement stage. However, they did not notice any change of product caused by the higher duties and taxes in their experience. Due to the sensitivity of data, the researcher did not have access to the related documents of the organisation. Hence, the observable evidences could not be recorded. Therefore, based on the interview evidence, level two was assigned to the organisation against the factor "Duties and Taxes".

Factor 1.3. Level of experience in off-site Construction methods

Factor	Level 1	Level 2	Level 3
F1. Operational challenges			
F1.3. Level of experience in Off-Site construction: How many off-site projects have been handled? What is the level of expertise of the organisation?	Are the design and project development teams well aware of techniques and methods involved in off-site construction practices?	Do all the senior management, project teams, construction workforce have significant experience in handling off-site construction projects?	Does the organisation maintain a structure with dedicated project team, and workforce that are specialised in off-site construction operations?

According to the participants, the organisation maintains a dedicated team for OSC projects. They also had a previous record of recruiting skilled designers and technicians for the OSC projects. The researcher noticed from the organisation's official website that they have a remarkable success rate in completing several housing and public buildings (one airport) with significant adoption of OSC techniques. According to this evidence, the organisation is at level three in terms of level of experience in OSC methods.

Factor 1.4. Promoting advantages of Off-Site Construction techniques

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			

F1.4. Promoting advantages of Off-Site construction techniques: How does the organisation handle the existing negative image (Goodier & Gibb, 2007; Arif. M *et. al.,* 2012) on off-site construction methods? Does it promote the advantages associated with OSC methods.	Does the organisation promote the potential benefits from off-site construction methods? Also, does the organisation conduct any enlightenment programs / one to one sessions with the potential clients to clarify their concerns?	Does the organisation maintain a calendar of awareness workshops? Also, does it brief the potential clients about the nature of work, application methods and achievable benefits before starting the project?	Does the organisation extensively promote the benefits of OSC products by showcasing successful projects, value proposition and product samples? Also does it include these promotional activities in the strategy?

According to the participants, the organisation participates in the exhibitions. However, there were no dedicated efforts from it to promote the OSC methods, although they mentioned the advantages of OSC methods in their success stories. The researcher observed this from the organisation's official webpage. Based on these two evidences, the organisation is at level one in the area of "Promoting Advantages of Off-Site Construction Techniques". The senior manager commented that, in recent times, the majority of their clients wanted to use pre-fab construction techniques (which can be tagged under OSC methods) to finish projects in a short time span. One of their housing clients has also expressed significant interest in implementing OSC methods for their housing project in Chennai, India.

Factor 1.5. Lead times

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.5. Lead times: What is the capability of the organisation in avoiding delays caused by long lead times?	Does the organisation consult the manufacturers before planning all critical events in the project schedule?	Are all events always planned according to the delivery schedules, to avoid time lags between the commencement and completion of the project?	Does the organisation closely work with manufacturers and all the supply chain involved in the projects? Also, does it collaborate

			with manufacturers and facilitate an in-house set up for greater control on time schedules?

The researcher identified that the project planning and project management teams always consider the delivery schedules of the OSC products and other related services. In the interview, the project manager expressed that they religiously follow the dates and schedules given by the vendors during the project awarding stage. Furthermore, the project planning team plans the processes accordingly. However, the organisation did not collaborate with any manufacturers of OSC systems. Since this was clarified during the interview, the researcher did not check for on-site evidence, and thus the organisation is at level two in the context of "Lead Times", which influences the OSC readiness of any organisation.

Factor 1.6. Client's resistance and scepticism

Factor	***Level 1***	***Level 2***	***Level 3***
F1. Operational challenges			
F1.6. Client's resistance and scepticism: How does the organisation address the resistance from clients?	Does the organisation explain to the client about the potential benefits of using OSC methods?	Does the organisation assure client about the added advantages with clear estimates and documentation along with detailed project plan?	Does the organisation involve client in key decision making process and clarify any concerns with clear evidence / past success stories? Also, does the organisation showcase successful projects and communicate the client about the progress of critical events with detail documentation?

According to the senior project manager, the clients demanded usage of OSC systems in the OSC projects they have done up to this date, so it was more client driven, and the client was key in the decision making process. However, the

organisation maintained clear documentation of the project cost and completion reports. According to the senior management, they commonly brief their clients about modern methods and innovations in the construction sector and their relevancy to the project. Therefore, level three can be assigned to the organisation in terms of the factor "Client's resistance and scepticism".

Factor 1.7.Guidance and information

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure.**
F1. Operational challenges			
F1.7. Guidance and information: To what extent, does the organisation support the field staff with guidance and information on Off-Site construction techniques?	Is the field workforce in the organisation provided with training, technical manuals and literature on new products? Also, is this accessible to the entire workforce?	Does the organisation arrange workshops and dedicated training from the manufacturers before implementing any new products?	Does the organisation have dedicated resources (instructor, technical team, library, training room, facilities which enable audio-visual demonstration) for training and guidance in office and on site?

According to the participants, the organisation religiously follows the training and up-skilling of the workforce. They consider this as a priority in their vision document. They also have a dedicated Research and Development (R&D) department. Furthermore, the researcher noticed the training schedule displayed on the notice board in the site office, and thus the organisation can be marked at level three in the context of "Guidance and Information" that influences the OSC readiness of any organisation.

F2.1. Transportation infrastructure

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F2. Broad execution strategy			
F2.1. Transportation infrastructure: What are the plans and arrangements made by the organisation to address the problems raised due to the existing poor road and transportation network?	Is the organisation aware of the minimum requirements to transport materials used in off-site construction projects?	If yes, does it critically evaluate the existing road and transportation network and customise their procurement strategy accordingly?	Does the organisation co-ordinate with the manufacturers at the initial stage and document route plan and schedules before placing the order (or) before starting the project?

The project planning team evaluates the existing road and other connecting networks of any potential site at the initial stage of planning. In one of the previous projects (international airport) they also requested that the manufacturers of OSC products submit on-site and off-site transportation and manoeuvring plans. However, the researcher could not find such a plan/evidence during the site visit on other projects. Despite this, based on the interviews, the organisation can be positioned at level three in regards to the transportation infrastructure for the OSC readiness.

F2.2. Manufacturing capacity

Factor	***Level 1***	***Level 2***	***Level 3***
F2. Broad execution strategy			
F2.2. Manufacturing capacity: How does the organisation handle the volume of products and other resources required?	Does the organisation estimate the requirement / quantities and consult the manufacturing facility before starting construction?	If yes, does the organisation complete the selection process at the early stage and place orders with effective planning?	Does the organisation evaluate the capacity of manufacturers to meet demand? Also, does the organisation enter into binding supply contracts?

According to the participants, the project planning and quantity surveyors team exchanges the products estimation and bill of quantities with all the vendors before starting a project; thus the selection of material will be done during the project planning stage. The organisation maintains in-house facilities for form-work systems. However, the management does not have any collaboration with other manufacturers. Therefore, the organisation reached level two of OSC readiness in terms of "Manufacturing Capacity".

F2.3. Shortage in availability

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F2. Broad execution strategy			
F2.3. Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported products with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers, to transfer and utilise their technology?

The senior manager explained the difficulties they have faced during one of the OSC projects. According to his comments, the shortage of OSC systems in India has caused delays in the project. The organisation does not have an alternative plan to address this risk, hence they are still at the level one, i.e. no clear application in addressing "Shortage in Availability".

F2.4. Availability of codes/standards

Factor	***Level 1***	***Level 2***	***Level 3***
F2. Broad execution strategy			
F2.4. Availability of codes / standards: The extent to which the	Are there any written standards/ guidelines available for all	Does the organisation strictly follow the standards	Does the organisation document the instructions before

organisation provide guidelines to the designers, operators and other construction workforce.	the members in project team?	throughout the design and construction stages?	design, and monitor the activities to ensure compliance with the standards?

According to the senior management, the manufacturers provide the design details and standards of the products and design and planning teams adhere to the standards. In the interview, the project manager commented, *"The imported products from Denmark and Germany possess detailed guidelines and standards. But, we do not observe the similar practice from the local manufacturers"*. The researcher also found no evidence of such standards and codes of practice during the site visit. Hence, the organisation is at level two in the preparedness for the adoption of OSC in the area "Availability of Codes and Standards".

F2.5. Maximising environmental performance in the life cycle

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F2. Broad execution strategy			
F2.5. Maximising environmental performance in the life cycle: To examine the strategies deployed by the organisation to maximise the usage of sustainable products and processes in various projects.	Is the organisation aware of the off-site products that are sustainable? If yes, does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimising waste during construction, to name a few) at the beginning of project?	Does the organisation establish a policy to use only certified or recommended products by the sustainable organisations? Does the organisation also register for sustainable building certification?

In the interview, the project manager expressed that the choice of method of construction is a client driven decision in a majority of the cases. Furthermore, the recent trend of embedding sustainable systems is also reflected in construction

industry. He has stated, *"All the recent projects are adopting certain degree of sustainable practices. Hence, the senior management in organisation is well aware of sustainable products"*. Furthermore, they also shared their experiences of successful adoption of waste minimising techniques in one of the housing projects. According to this, the organisation reached level two in terms of "Maximising Environmental Performance in the Life Cycle".

In addition, the senior project manager expressed that this sub-factor was not significant to assessing the OSC readiness of an organisation. Furthermore, he felt that it would be practically difficult to evaluate this factor in OSC projects since the majority of the OSC products are also eco-friendly. The researcher explained to the manager about the derivation (the process of literature review – questionnaires – interviews) of these factors and the development of the present refined framework. The manager still recommended that the researcher remove this sub factor from the framework.

F2.6. Capital cost

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F2. Broad execution strategy			
F2.6. Capital cost: What is the financial preparedness of the organisation in terms of the capital investment?	Does the organisation allocate dedicated funds to support and accelerate the adoption of off-site construction techniques?	If yes, does the organisation maintain a financial strategy for future investments?	Does the organisation establish a policy on the investment diversification and strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?

In the interview, the senior project manager answered that he is unaware of financial details of the organisation like capital cost. Furthermore, he suggested approaching the finance department for more details. The researcher attempted to interview the senior staff in the finance department, but they did not disclose any details due to the

sensitive nature of financial documents. However, he shared that the general practice of the organisation was to allocate funds for research and innovation. Therefore, the researcher assigned level one against the factor "Capital Cost".

F3. Certainty in planning

F3.1. Cost certainty

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F3. Certainty in planning			
F3.1. Cost certainty: To what extent, does the organisation plan and monitor the budget performance?	Does the organisation document the estimates at the beginning of the project? Also, is there any evidence of integration between project administration and control?	If yes, does the organisation closely monitor the project expenses and compare with the estimates? Also, does it take measures to avoid any variation?	Does the organisation implement a standardised project financial accounting and management systems?

The organisation practices a standard method of recording the cost of each project. There is a central finance system which monitors the documentation of all the projects, and according to this the organisation achieved level three of OSC readiness in the area "Cost Certainty".

F3.2. Time certainty

Factor	***Level 1***	***Level 2***	***Level 3***
F3. Certainty in planning			
F3.2. Time certainty: How does the organisation plan the critical activities? What is the capability of the organisation to ensure that there is no variation	Does the organisation identify critical activities and follow their sequence of execution?	Does the organisation monitor and review the process and take precautions to avoid any delay?	Does the organisation establish a policy to optimise performance through ensuring process standardisation?

between the estimated and actual completion date?			

According to the senior project manager, the organisation follows a project plan with all the critical activities in the required sequence. The project team closely monitors the activities on-site and takes measures to avoid confusion and delays. However, from the interview it was evident that no standard policy is adopted for the planning of OSC project; hence, the maturity level of the organisation in "Time Certainty" is level two.

F4. Operational efficiency

F4.1. Minimising on-site duration

Factor	***Level 1*** **No clear application**	***Level 2*** **Frequent application. Lack of standard practice**	***Level 3*** **Established operating procedure**
F4. Operational efficiency			
F4.1. Minimising on-site duration: What is the capability of the organisation to reduce / minimise the duration of non-critical activities during construction on site?	Does the organisation identify and control / avoid the non-critical activities during planning and on site?	Does the organisation efficiently plan and execute all parallel activities during planning and on site?	Does the organisation ensure that all appropriate off-site activities are completed before starting erection on construction site? Also, does it standardise the on-site working process?

In the interview, the senior project manager explained the customised method of project planning. In this, the project planning team considers all non – critical activities during the planning stage. During the execution, they ensure that all parallel activities are being executed according to the plan on-site; however, according to the manager, this approach slightly varies from project to project depending on the nature/type of the project. He discussed this in detail with the example of the Housing project and the International Airport project. In the airport

project, the planning team could not apply the standard method due to operational reasons. In the end, the researcher marked the level of maturity of the organisation at level two and the senior project manager agreed.

F4.2. Prompt delivery

Factor	***Level 1***	***Level 2***	***Level 3***
F4. Operational efficiency			
F4.2. Prompt delivery: How does the organisation ensure prompt delivery of products and services?	Does the organisation closely work with supply chain and logistics involved in various projects?	Does the organisation collaborate with selected vendors and consultants involved in various projects?	Does the organisation maintain a directory of efficient vendors and service providers based on their performance? Is there a practice of partnering with providers / vendors?

The organisation has collaborations with selected vendors such as HVAC (Heating, Ventilation, and Air Conditioning) and electrical consultants. Furthermore, they also have in-house facilities of pre-cast slabs and maintain fabrication yards on-site. Thus, according to the senior manager, the organisation ensures prompt delivery of a majority of the services and products. Hence, the organisation reached level three of OSC readiness in terms of “Prompt Delivery”.

Table 5.5. Summary of results of Organisation B

Factor	**OSC readiness level of Org. B**
F1. Operational challenges	
F1.1. Complex interfacing between the systems	Level - 3
F1.2. Duties and taxes	Level – 2
F1.3. Level of experience in Off-Site Construction methods	Level – 3
F1.4. Promoting advantages of Off-Site construction techniques	Level – 1
F1.5. Lead times	Level – 2

F1.6. Client resistance and scepticism	Level – 3
F1.7. Guidance and information	Level – 3
F2. Broad execution strategy	
F2.1. Transportation infrastructure	Level – 3
F2.2. Manufacturing capacity	Level – 2
F2.3. Shortage in local availability	Level – 1
F2.4. Availability of codes / standards	Level – 2
F2.5. Maximising environmental performance in the life cycle	Level - 2
F2.6. Capital cost	Level – 1
F3. Certainty in planning	
F3.1. Cost certainty	Level – 3
F3.2. Time certainty	Level – 2
F4. Operational efficiency	
F4.1. Minimising on-site duration	Level - 2
F4.2. Prompt delivery	Level - 3

5.4. Case study 3

5.4.1. Background of the organisation

Organisation C was founded in 1998. They offer engineering, design, construction and procurement services for various building and infrastructure projects. Further details about the organisation are shown in Table 5.6.

Table 5.6 Profile of Organisation C

Year of establishment	1998
Areas of specialisation	Engineering, design, construction and procurement for Biopharmaceutical, Automobile, Healthcare/Hospitals, Residential/Corporate Offices and Energy & Sustainability projects.
Location	Mumbai – India (other locations include New Delhi, Ahmadabad and Hyderabad).

5.4.2. Evaluation of OSC readiness of organisation C

The researcher conducted interviews with one senior project manager, two architects and one technical engineer to study the case of Organisation C. Furthermore, the researcher also visited one of the ongoing projects. In this project, organisation involves rendering services to design and build a beverages' manufacturing factory. The researcher noted the findings from the interviews and observations during the site visit.

Factor 1. Operational challenges

Factor 1.1. Complex interfacing between the systems

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure.***
F1. Operational challenges			
F1. 1. Complex interfacing between the systems: How does the organisation respond to the challenges in assembling individual systems / products of a complex nature?	Is the workforce aware of the assembling techniques and interfacing of different products?	Does the organisation demonstrate how to assemble new, complex structures before implementing them on – site?	Does the organisation expedite the learning curve from one off-site project to another project, through integrating training programs in the strategy? Also, does the organisation prioritise capacity building in the policy?

According to the participants, the organisation conducts staff training and briefing sessions before executing work. However, there is no standard practice of regular training. In the previous projects, the staff encountered challenges in working with new imported systems. Training and guidance was introduced as an immediate response to addressing those challenges. Also, the organisation recruits staff according to requirements. During the site visit, the researcher observed some charts with details of the project scheduling and health & safety measures. It can be said from the above, that the organisation achieved level two in terms of the "Complex

Interfacing Between the Systems" factor. The research concluded from the interviews and observations that the management supports training and up skilling; however, this is not part of the organisation's strategy.

Factor 1.2. Duties and taxes

Factor	*Level 1*	*Level 2*	*Level 3*
F1. Operational challenges			
F1.2. Duties and taxes: How does the organisation consider the leviability of duties and taxes on the Off-Site products?	Does the organisation identify the potential challenges associated with the duties and taxes on the Off-Site products?	Does the material procurement strategy of the organisation consider both imported and domestic Off-Site products? Also, does the organisation maintain any records to monitor the duties and taxes payable / already paid?	Does the organisation achieve optimal utilisation of imported and domestic products? Does it always prioritise the Off-Site products entitled with incentives or exemptions from the taxes?

A majority of the participants avoided the question on "Duties and Taxes", with one of the interviewees saying that the project teams are unaware of them. The two architects stated, *"We only suggest the products and materials in the design stage. In the next phase, the procurement team prepares the appraisal report on the products. Based on the availability of materials, we freeze the final design and present to the client"*. According to the project manager, the procurement team identify the list of potential taxes on the OSC products and communicate this report to the finance division. The researcher also noted from the website that the organisation assisted one of their clients with paper work for a tax deduction certification. Therefore, it is understood that the organisation evaluates the legibility of duties and taxes on the OSC products, and hence the organisation achieved level two of the maturity in this factor.

Factor 1.3. Level of experience in off-site construction methods

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F1. Operational challenges			
F1.3. Level of experience in Off-Site construction: How many off-site projects have been handled? What is the level of expertise of the organisation?	Are the design and project development teams well aware of techniques and methods involved in off-site construction practices?	Do all the senior management, project teams, construction workforce have significant experience in handling off-site construction projects?	Does the organisation maintain a structure with dedicated project team, and workforce that are specialised in off-site construction operations?

The organisation is comprised of a combination of beginners in the area of OSC and experienced staff in senior positions. The design and project development team is dominated by experienced staff who worked on more than two OSC projects. On the other hand, the construction work force had minimal knowledge of OSC products. The researcher interviewed two on-site workers during the site visit, and both of them answering that it was their first time working on such projects. They called it as "*special project*". Interestingly, the senior project manager stated that Organisation C is evaluating the possibilities of maintaining a dedicated team for OSC projects. It can be concluded that the current level of OSC experience in the organisation is at the level two. However, if the management succeeds in maintaining a dedicated team of experts for OSC projects, the organisation has the scope to reach level three.

F1.4. Promoting advantages of off-site construction techniques

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F1. Operational challenges			
F1.4. Promoting advantages of Off-	Does the organisation	Does the organisation	Does the organisation

Site construction techniques: How does the organisation handle the existing negative image (Goodier & Gibb, 2007; Arif. M *et. al.,* 2012) on off-site construction methods? Does it promote the advantages associated with OSC method?	promote the potential benefits from off-site construction methods? Also, does the organisation conduct any enlightenment programs / one to one sessions with the potential clients to clarify their concerns?	maintain a calendar of awareness workshops? Also, does it brief the potential clients about the nature of work, application methods and achievable benefits before starting the project?	extensively promote the benefits of OSC products by showcasing successful projects, value proposition and product samples? Also does it include these promotional activities in the strategy?

The researcher interviewed senior project managers and senior architects regarding this factor. According to the participants, the organisation did not conduct promotional programmes. The senior architect expressed that they participated in two design competitions and illustrated the advantages of OSC methods through design. The biggest public platform, where the organisation demonstrated their skills in the area of OSC, was through these design competitions. According to the senior project manager, the management of the organisation published the success stories and award winning projects on the official website. According to them, the website promotes their name and also reaches the targeted audience. The researcher accessed the website of the organisation and identified information on the success stories. The researcher also observed similar data and pictures on the display boards in the visitors lobby. Despite the success stories and award winning projects, the organisation did not include promotion and awareness campaigning in their strategy. Due to this, the organisation stood at level two in terms of the factor of "Promoting Advantages of Off-Site Construction Techniques" in the OSC readiness framework.

Factor 1.5. Lead times

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F1. Operational challenges			
F1.5. Lead times: What is	Does the organisation consult	Are all events always planned according to	Does the organisation

the capability of the organisation in avoiding delays caused by long lead times?	the manufacturers before planning all critical events in the project schedule?	the delivery schedules, to avoid time lags between the commencement and completion of the project?	closely work with manufacturers and all the supply chain involved in the projects? Also, does it collaborate with manufacturers and facilitate an in-house set up for greater control on time schedules?

The senior project manager demonstrated that the project planning team always considers the time frames given by the manufacturers and supplier while planning the activities sheet and time charts. He expressed that they always adhered to the delivery schedules in the OSC projects. He also commented, "*We make sure that ample time was given to the manufacturers".* The researcher also learned about the collaboration between the organisation and two large manufacturers of OSC products. One of the senior managers also mentioned about the collaboration with the manufacturers of steel roofing and flooring systems. The organisation maintains a close working relation with all consultants and vendors. According to the participants, the management repeats the vendors for various projects. The senior project manager stated that the close association and multiple follow-ups result in the on-time delivery of various products. Therefore, the organisation achieved level three of the OSC readiness in the framework.

Factor 1.6. Client's resistance and scepticism

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F1. Operational challenges			
F1.6. Client's resistance and scepticism: How does the organisation address the resistance from clients?	Does the organisation explain to the client about the potential benefits of using OSC methods?	Does the organisation assure client about the added advantages with clear estimates and documentation along with detailed project plan?	Does the organisation involve client in key decision making process and clarify any concerns with clear evidence / past success stories?

			Also, does the organisation showcase successful projects and communicate the client about the progress of critical events with detail documentation?

The organisation encourages their clients to adopt OSC methods and other new technologies. One of the architects explained that the consultants first note the client's requirements in the first meeting. The design and engineering team evaluates the project brief and assesses the scope for implementation of OSC and other modern methods. Based on this report, the design team briefs the client about the scope of construction with OSC methods. Furthermore, they demonstrate the potential advantages from using these methods. In addition to this, they also showcase the examples from previous projects. The senior architect stated, "*Some of our corporate clients have approached us with a clear thought to adopt OSC methods in their projects. Also, there were occasions where our clients decided to adopt OSC techniques at the end of the decision making process. This could be because of the nature of the clients' organisation and decision making methods.*" According to the architects, the resistance and scepticism from the clients is trivial. Based on this, it can be argued that the organisation is at level three in the area "Client Resistance and Scepticism".

F1.7.Guidance and information

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F1. Operational challenges			
F1.7. Guidance and information: To what extent, does the organisation support the field staff with guidance and information on	Is the field workforce in the organisation provided with training, technical manuals and literature on new products?	Does the organisation arrange workshops and dedicated training from the manufacturers before implementing any	Does the organisation have dedicated resources (instructor, technical team, library, training room, facilities which enable audio-

Off-Site construction techniques?	Also, is this accessible to the entire workforce?	new products?	visual demonstration) for training and guidance in office and on site?

According to the participants, the organisation provides guidance and information about the OSC products to the design and engineering team. The architects stated that they have access to various information and literature regarding the new construction methods in the library. On the other hand, the management provides training to the entire workforce at the beginning of every OSC project. However, the organisation does not have any dedicated resources for such training sessions. One of the on-site workers commented, "*When we have any doubts, we approach our supervisor. He further conveys it to the site office. Our project manager or technical team member attends our enquiry and explains us on-site*." The above comment illustrates that the management enabled technical support for on-site workers; however, there was no dedicated instructor. Also, the researcher found from the interview that there are no dedicated resources available for all the employees. Therefore, the organisation demonstrated the OSC readiness of level two.

F2.1. Transportation infrastructure

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F2. Broad execution strategy			
F2.1. Transportation infrastructure: What are the plans and arrangements made by the organisation to address the problems raised due to the existing poor road and transportation network?	Is the organisation aware of the minimum requirements to transport materials used in off-site construction projects?	If yes, does it critically evaluate the existing road and transportation network and customise their procurement strategy accordingly?	Does the organisation co-ordinate with the manufacturers at the initial stage and document route plan and schedules before placing the order (or) before starting the project?

In the interview, the participants stated that they are aware of the special requirements involved in working with OSC products. However, they do not exercise on the details of transportation planning. According to the project manager, a majority of the previous projects have appropriate accessibility and ample space in the site. So, the manufacturers and other suppliers deliver products to the storage facility in the site. The site supervisor issues all the material as per the estimation. The management uses large cranes and other construction transportation equipment to deliver the products to the actual work place. Since the organisation is aware of the minimum requirements in transporting OSC products, it can be said that the organisation achieved level one in terms of the "Transportation Infrastructure" factor in the OSC readiness framework.

F2.2. Manufacturing capacity

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F2. Broad execution strategy			
F2.2. Manufacturing capacity: How does the organisation handle the volume of products and other resources required?	Does the organisation estimate the requirement / quantities and consult the manufacturing facility before starting construction?	If yes, does the organisation complete the selection process at the early stage and place orders with effective planning?	Does the organisation evaluate the capacity of manufacturers to meet demand? Also, does the organisation enter into binding supply contracts?

In the interview, the participants shared that the procurement and logistics teams of the organisation work closely with the suppliers and manufacturers. According to the participants, the organisation maintains collaborations with some of the manufacturers and also ensures that all the manufacturers abide by the terms of the contract. The senior project manager shared one of the experiences from the previous projects. In one of them, the manufacturer of concrete slabs delayed the delivery for inexcusable reasons. The management penalised the contractor and did not award any new contact. From the above, it can be argued that the organisation

reached level two of OSC readiness in terms of achieving huge demand of OSC products.

F2.3. Shortage in availability

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F2. Broad execution strategy			
F2.3. Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported products with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers, to transfer and utilise their technology?

The organisation currently does not have any in-house facility. However, the senior project manager conveyed that the management is considering establishing three manufacturing facilities. Furthermore, the organisation established affiliation and partnership with international construction companies for technical consultation and knowledge exchange. According to the senior project manager, this strategic partnership would strengthen the organisation in delivering efficient services and products. Based on the interview findings, the organisation can be assigned level three in terms of the factor "Shortage in Availability".

F2.4. Availability of codes/standards

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F2. Broad execution strategy			
F2.4. Availability of codes / standards: The extent to which the organisation provide guidelines to the designers, operators and other construction workforce.	Are there any written standards/ guidelines available for all the members in project team?	Does the organisation strictly follow the standards throughout the design and construction stages?	Does the organisation document the instructions before design, and monitor the activities to ensure compliance with the standards?

In the interview, the architects reported that they received the standards and user manuals at the beginning of the design stage. The design head ensures that all the guidelines are obeyed in all the projects. A similar procedure occurs in the OSC projects. Project managers' monitoring ensures successful application of these standards in the execution stage. Therefore, the organisation achieved level two of OSC readiness in this area.

F2.5. Maximising environmental performance in the life cycle

Factor	*Level 1*	*Level 2*	*Level 3*
F2. Broad execution strategy			
F2.5. Maximising environmental performance in the life cycle: To examine the strategies deployed by the organisation to maximize the usage of sustainable products and processes in various projects.	Is the organisation aware of the off-site products that are sustainable? If yes, does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimizing waste during construction, to name a few) at the beginning of project?	Does the organisation establish a policy to use only certified or recommended products by the sustainable organisations? Does the organisation also register for sustainable building certification?

In the interview, the senior project manager expressed that the organisation is committed to spreading the green footprint. He also highlighted that sustainability is embedded in the vision document of the organisation. The participants reported that the organisation is constantly deploying new energy saving technologies in the operations. The organisation also successfully commissioned a "LEED GOLD" certified facility and a "LEED SILVER" certified facility. Furthermore, the participants also shared that the project teams also maintained the documentation of energy assessments and audits. Based on the interview findings, the researcher assigned level three of OSC readiness in this factor.

F2.6. Capital cost

Factor	*Level 1* *No clear application*	*Level 2* *Frequent application. Lack of standard practice.*	*Level 3* *Established operating procedure*
F2. Broad execution strategy			
F2.6. Capital cost: What is the financial	Does the organisation allocate	If yes, does the organisation	Does the organisation establish a policy on

preparedness of the organisation in terms of the capital investment?	dedicated funds to support and accelerate the adoption of off-site construction techniques?	maintain a financial strategy for future investments?	the investment diversification and strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?

The senior project manager commented that the organisation is planning to increase the utilisation of existing resources and extending the envelop through implementing new technologies in construction. However, the financial planning is exclusively dealt by the finance division. So the project and design teams are unaware of the capital investment. Based on the interview findings, it can be argued that the organisation is at level one in regard to capital investment.

F3. Certainty in planning

F3.1. Cost certainty

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F3. Certainty in planning			
F3.1. Cost certainty: To what extent does the organisation plan and monitor the budget performance?	Does the organisation document the estimates at the beginning of the project? Also, is there any evidence of integration between project administration and control?	If yes, does the organisation closely monitor the project expenses and compare with the estimates? Also, does it take measures to avoid any variation?	Does the organisation implement a standardised project financial accounting and management systems?

According to the participants, the management established a standard procedure in terms of cost planning and monitoring. The project manager explained that the organisation is aiming to achieve cost effectiveness. He also shared an example from one of their recent projects, where they completed the entire project under the planned estimation. In addition, the organisation also follows a standard project finance management system for all the projects, and they apply the same method to

the OSC endeavours. However, from the interviews, the researcher found that there is no customised policy for the needs of OSC projects; therefore, the organisation achieved level two in the area of cost certainty.

F3.2. Time certainty

Factor	*Level 1*	*Level 2*	*Level 3*
F3. Certainty in planning			
F3.2. Time certainty: How does the organisation plan the critical activities? What is the capability of the organisation to ensure that there no variation between the estimated and actual completion date?	Does the organisation identify critical activities and follow their sequence of execution?	Does the organisation monitor and review the process and take precautions to avoid any delay?	Does the organisation establish a policy to optimise performance through ensuring process standardisation?

The organisation embedded lean construction practices in their policies. This highlights their commitment and approach towards achieving time certainty. According to the senior project manager, the organisation established a practice of submitting a "pre-construction" report before starting the actual construction. This report presents the execution, planning, scheduling, design management, constructability review, bidding, logistics, risk analysis, MEP coordination, project reporting, value engineering, cost planning and project controls of any project. According to the senior project manager, it ensures that all the critical events are executed according to the planned schedule. From the interview, it is evident that the organisation has an established policy for optimising performance; hence, the researcher assigned level three to this factor.

F4. Operational efficiency

F4.1. Minimising on-site duration

Factor	*Level 1* *No clear application*	*Level 2* *Frequent application. Lack of standard practice.*	*Level 3* *Established operating procedure*
F4. Operational efficiency			
F4.1. Minimising on-site duration:	Does the organisation identify	Does the organisation	Does the organisation ensure

What is the capability of the organisation to reduce / minimize the duration of non-critical activities during construction on site?	and control / avoid the non-critical activities during planning and on site?	efficiently plan and execute all parallel activities during planning and on site?	that all appropriate off-site activities are completed before starting erection on construction site? Also, does it standardise the on-site working process?

Regarding this factor, the researcher received responses from one senior project manager, two project managers and one site supervisor. The participants stated that the management ensures that all the supply chain adheres to the agreed delivery schedules. The senior project manager explained that the management embedded lean practices in the organisation's policy document. The project management team effectively coordinates and ensures no deviation in executing all critical activities. They constantly monitor and incorporate any delayed activities into a fast-track project delivery schedule for successful and timely completion. In addition to this, the organisation also adopted a Modular Project Delivery (MPD) approach for OSC projects. Based on the interview findings, the researcher assigned level three to the efficiency and OSC readiness of the organisation in the area "Minimising On-site Duration".

F4.2. Prompt delivery

Factor	***Level 1 No clear application***	***Level 2 Frequent application. Lack of standard practice.***	***Level 3 Established operating procedure***
F4. Operational efficiency			
F4.2. Prompt delivery: How does the organisation ensure prompt delivery of products and services?	Does the organisation closely work with supply chain and logistics involved in various projects?	Does the organisation collaborate with selected vendors and consultants involved in various projects?	Does the organisation maintain a directory of efficient vendors and service providers based on their performance? Is there a practice of partnering with providers / vendors?

According to the participants, the organisation maintains collaborations with local and international vendors. In addition, the management also performs supplier assessments and audits. The project manager shared that the supply chain management team states the procurement specifications during the pre-construction phase. Furthermore, the management awards contracts to reliable and efficient vendors. According to the senior project manager, the organisation adopted this policy to achieve schedule optimisation. They also developed and led a Modular Construction Technologies tour in order to identify the best vendors in the industry. This reflects that the organisation standardised the selection and awarding procedure for the OSC projects. Therefore, the researcher assigned level three against the factor "Prompt Delivery".

Table 5.7. Summary of results of Organisation C

Factor	**OSC Readiness level of Org. C**
F1. Operational challenges	
F1.1. Complex interfacing between the systems	Level – 2
F1.2. Duties and taxes	Level – 2
F1.3. Level of experience in Off-Site Construction methods	Level – 2
F1.4. Promoting advantages of Off-Site construction techniques	Level – 2
F1.5. Lead times	Level – 3
F1.6. Client resistance and scepticism	Level – 3
F1.7. Guidance and information	Level – 2
F2. Broad execution strategy	
F2.1. Transportation infrastructure	Level –1
F2.2. Manufacturing capacity	Level – 2
F2.3. Shortage in local availability	Level – 3
F2.4. Availability of codes / standards	Level – 2
F2.5. Maximising environmental performance in the life cycle	Level – 3
F2.6. Capital cost	Level – 1
F3. Certainty in planning	
F3.1. Cost certainty	Level – 2
F3.2. Time certainty	Level – 3
F4. Operational efficiency	

F4.1. Minimising on-site duration	Level - 3
F4.2. Prompt delivery	Level - 3

5.4. Chapter Summary

The purpose of this chapter was to present the validation of the Off-Site Construction readiness framework. Three case studies were analysed in order to validate the framework and test its applicability in practice. This task has been carried out on real life construction organizations of different scale with different objectives. The procedures of validation were carried out using interviews, document analysis, and other observable evidences. All the three organisations had used both OSC practices along with the traditional methods of construction. The three case studies demonstrated that the proposed OSC Readiness framework was able to assess the level of OSC readiness of the organisations. The results were presented in table 5.7, and 5.8 below. Through the findings, it can be understood that OSC practices were evident in all three organisations.

Table 5.8. Summary of results obtained from the case studies

Factor	**OSC Readiness level of Org. A**	**OSC Readiness level of Org. B**	**OSC Readiness level of Org. C**
F1. Operational challenges			
F1.1. Complex interfacing between the systems	Level - 2	Level - 3	Level – 2
F1.2. Duties and taxes	Level - 2	Level – 2	Level – 2
F1.3. Level of experience in Off-Site Construction methods	Level - 1	Level – 3	Level – 2
F1.4. Promoting advantages of Off-Site construction techniques	Level – 3	Level – 1	Level – 2
F1.5. Lead times	Level – 3	Level – 2	Level – 3
F1.6. Client resistance and scepticism	Level – 2	Level – 3	Level – 3
F1.7. Guidance and information	Level – 3	Level – 3	Level – 2
F2. Broad execution strategy			
F2.1. Transportation infrastructure	Level – 2	Level – 3	Level –1
F2.2. Manufacturing capacity	Level – 3	Level – 2	Level – 2
F2.3. Shortage in local availability	Level – 1	Level – 1	Level – 3
F2.4. Availability of codes / standards	Level –3	Level – 2	Level – 2

F2.5. Maximising environmental performance in the life cycle	Level - 1	Level - 2	Level – 3
F2.6. Capital cost	Level - 1	Level – 1	Level – 1
F3. Certainty in planning			
F3.1. Cost certainty	Level - 2	Level – 3	Level – 2
F3.2. Time certainty	Level - 2	Level – 2	Level – 3
F4. Operational efficiency			
F4.1. Minimising on-site duration	Level - 2	Level - 2	Level - 3
F4.2. Prompt delivery	Level - 3	Level - 3	Level - 3

Table 5.9. Summary of current OSC readiness of the three organisations (case studies)

Factor	Org. A	Org. B	Org. C
F1. Operational challenges			
Level - 1	1	1	0
Level - 2	3	2	5
Level - 3	3	4	2
F2. Broad execution strategy			
Level - 1	3	2	2
Level - 2	1	3	2
Level - 3	2	1	2
F3. Certainty in planning			
Level - 1	0	0	0
Level - 2	2	1	1
Level - 3	0	1	1
F4. Operational efficiency			
Level - 1	0	0	0
Level - 2	1	1	0
Level - 3	1	1	2

All the three organisations have reached level two in terms of “Duties and taxes”. Hence, it can be said that all the organisations have considered the maintenance of records, and monitoring the tax and duty payments as part of the material procurement strategy. Organisation B had established a standard procedure in majority of their operations. This reflected in the organisation’s practice in terms of working with complex OSC products; recruiting experienced workforce, addressing the scepticism from the clients, and providing training sessions and guidance to the

staff. On the other hand, Organisation C had demonstrated more frequent application of OSC requisites at operational level. However, it is yet to establish a standard operational procedure to achieve optimum advantage from the OSC techniques. Kamar et al., (2009) stated that the design and illustration of products must be documented in systematic ways to ensure process standardisation is achieved during installation and construction phases. The need for standardisation in design and project function was emphasized by several researchers (Tam et al., 2007; Gibb and Isack, 2001; Pan et al., 2008 and Azman et al., 2010) in the existing literature.

Further, results against the constructs of broad execution strategy have revealed interesting findings. None of the representatives of the three organisations have shared minimal to no knowledge about "capital cost". This could be due to the sensible nature of the data related to cost and finance. Organisation A and C have established standard practices in two areas, while organisation B had attained level 3 in only one area, that is in transportation infrastructure.

The OSC readiness framework assessed the organisations in certainty planning and operational efficiency factors. It was evident that all the three organisations have attained maturity beyond the first level. Organisation A had a clear practice of applying standardised cost and planning methods. However, it was lacking a strategic approach in this area. On the other hand, Organisation B and Organisation C have achieved level 3 in cost certainty and time certainty respectively. Similarly, all the organisations have demonstrated clear application in both minimising on-site duration and prompt delivery. The three organisations have crossed level one, and achieved third level maturity in performing prompt delivery. This shows that the organisations have embraced strategic approach to apply standard procedure in delivery methods and performance.

This framework now provides a formal method to be used by construction organisations in India to assess their readiness before adopting OSC methods. In addition, this framework also asserts the scope for up-gradation within the processes of the organization. The next chapter presents the discussion on the research findings obtained from the three data collection stages.

Chapter 6 | Discussion and Findings

6.1 Introduction

As part of this research, this chapter discusses the findings from the qualitative and quantitative data collection and analysis. These findings answered the research questions. The adopted research design was earlier discussed in detail in the research methodology and design chapter. The current research is divided into four stages. In the initial step, the researcher conducted a literature review of the Off-Site Construction methods, the status of OSC in India and assessment tools in construction research and industry. This literature review has also helped to identify critical factors affecting the adoption of OSC in various countries. The summary of these findings from the literature was discussed at the end of the second chapter of current thesis.

In the first stage, the researcher collected data through quantitative and qualitative methods. The findings from the questionnaire survey have illustrated the current state of OSC in India. They have also identified the critical factors, drivers and barriers towards the adoption of OSC in India. Furthermore, the results from the questionnaires were findings from the semi-structured interviews have assisted the researcher in defining the scope of the factors involved. Thus, the findings from the first two stages have constructed the conceptual OSC readiness framework.

The second stage has refined the conceptual OSC readiness framework through semi–structured interviews. In this stage, the researcher has assessed the conceptual framework by posing five major questions. Furthermore, the researcher has incorporated the recommendations from these findings and refines the framework accordingly. In the third stage, the researcher has validated the refined framework through case studies. The researcher tested the refined OSC readiness framework in three Indian construction organisations which are practicing OSC techniques. This chapter will discuss the findings from the multiple data collection exercises in detail.

6.2. Mix of Quantitative and Qualitative findings

As mentioned above, the researcher adopted a mixed methods research approach to achieve the research objectives. The research has involved both quantitative and qualitative data collection and analysis. In the quantitative method, the researcher

implemented a self-administrated questionnaire. Similarly, in the qualitative method the researcher conducted semi-structured interviews. The results from the questionnaires highlighted the drivers and barriers towards the adoption of OSC in India, and also documented the factors influencing OSC in India. Furthermore, these results have also verified the findings from the questionnaires through semi-structured interviews.

6.2.1. Framework Development Findings

In this stage, the researcher initiated the process of developing a framework that could assess the OSC readiness of construction organisations in India. As discussed earlier, the researcher conducted extensive desktop study and reviewed the literature to identify various factors affecting the implementation of OSC across the globe. In addition, the researcher also analysed available maturity models, readiness tools and some models in the area of OSC. Later, the researcher has identified the factors influencing the uptake and success of OSC in India through **self-administered questionnaires**. After obtaining the responses from the questionnaires, the researcher conducted **semi-structured interviews** to verify the results of the questionnaires. The semi-structured interviews also assisted the researcher in restructuring the framework constructs in order to develop the OSC readiness framework for the Indian context. During the semi-structured interviews, the researcher also examined the derived maturity levels (three levels) from the literature. Thus, the OSC readiness framework was developed from the data gathered through self-administered questionnaires and semi-structured interviews.

6.2.1.1. Questionnaire findings

The researcher received 204 responses for the self-administered questionnaire from Architectural, Engineering and Construction professionals of various construction organisations in India. The research questionnaire consisted of three sections. The first section enquired about the general information about the respondents. The second section was aimed at gathering data about the nature of the organisation and respondent's experience in the field of construction. The third section presented the list of factors that were extracted from the literature in order to know the impact of the application on OSC in India. In detail, the third section seek information on the respondents' current experience in the use of OSC methods, a view on OSC in India, an opinion on the advantages of using OSC and the influence of various factors on

the adoption of OSC in Indian construction organisations. The data obtained from the questionnaires was analysed through descriptive statistical analysis and factor analysis methods.

The researcher has investigated the influence of several variables through the questionnaire survey. Variables such as ensuring time certainty, speed delivery, minimising on-site duration and lack of transportation & infrastructure facilities were highlighted by the majority of the respondents under high or very high influencing factors. The questionnaire results have also shown that, minimising on-site duration has a very high to high influence on the Off-Site construction practices in India. On the other hand, the availability of codes and standards has very less influence on the adoption on Off-Site Construction practices in India. Hence, it can be said that the afore-mentioned factors have highly influenced the application of OSC practices in India.

Furthermore, the researcher has also investigated the **drivers and barriers** towards the adoption of OSC practices in the present scenario of Indian construction industry. The key drivers and barriers from this exercise were demonstrated in the table below. Here, 151 participants felt that "Ensuring cost certainty" encourages the adoption of Off-Site construction techniques in India. Following this, 130 participants marked "Ensuring time certainty". On the other hand, a risk averse culture was highlighted as a barrier by 132 respondents. According to the data analysis, "complex interfacing between the systems", "client resistance and scepticism and "not locally unavailable" were some of the other barriers.

Table 6.1. Drivers and barriers towards the adoption of Off-Site construction techniques in India

DRIVERS
Ensuring cost certainty
Ensuring time certainty
Speed delivery
Minimizing on-site duration
Achieving high quality
Addressing the skilled labour shortage
Reducing health and safety risks
Restricted site specifics
Huge demand and delivery requirements

Economy of scale
Reducing environmental impact during construction
Maximising environmental performance in the life cycle
Few codes and standards available
Skills shortage
BARRIERS
Longer lead times
Client resistance and scepticism
Lack of guidance and information
Negative image
Not locally available
No experience of its use
Duties and taxes
Complex interfacing in between systems
Risk averse culture
Lack of manufacturing capacity
Lack of transportation infrastructure
Higher capital cost

6.3. Factor Analysis

The researcher has conducted factor analysis to categorise the variables identified. The questionnaire listed the 26 variables, which were identified from the literature review. All the participants have recorded their responses against the variables respectively. The researcher then conducted the factor analysis of the collected data during the analysis stage. After factor analysis, the number of variables were reduced to 17. The researcher conducted Principal Component Analysis, through forcing the number of factors to four (4) in maximum likelihood method with varimax rotation technique.

In the later stage, the researcher exercised the grouping of variables. The grouping was led by the loadings for all 17 variables. Hence, each group was separated based on the loadings of more than 0.5.Thus, the variables were categorised into four groups. According to this, complex interfacing between systems, duties and taxes, no experience of its use, risk averse culture, longer lead times, client resistance & scepticism and lack of guidance and information are rewarded under Factor -1. Similarly, a lack of transportation infrastructure, lack of manufacturing capacity, not locally available, few codes/standards available, negative image and higher capital cost are loaded on to Factor-2. Other factors such as ensuring cost certainty and

ensuring time certainty, minimising on-site duration and speed delivery were considered under Factor-3 and Factor-4 respectively.

6.4. Frame work design

In this stage, the researcher documented the four groups and elaborated the scope of each variable of all the factors. This was discussed in detail in chapter four. The scope of these variables enabled the categorisation and naming of the factors. Thus, the researcher titled the first factor **"Operational challenges"**, since the majority of the variables of this group, such as working with complex systems, level of experience and skill, lead times and guidance and information dealt with the operations of OSC projects. Similarly, the second factor was named as **"Strategy"**, where the variables under this factor dealt with the strategic elements. For example, transportation infrastructure and capital costs focus significantly on the strategic attributes of the organisation. Factor three was named as **"Certainty planning"** - the variables under this factor dealt with the cost and time certainty. Similarly, the fourth factor was named as **"Operational efficiency"**; the variables in this factor assessed the efficiency of the organisation in terms of achieving prompt delivery and minimising on-site duration.

Furthermore, the researcher developed a framework with the four factors, along with the 17 sub–factors. The framework is discussed in detail in Chapter Four. The framework developed was then refined through semi-structured interviews. During the semi-structured interviews, the respondents suggested changes to some of the factors and also to the scope and character of the sub-factors. The revised factors and sub-factors were illustrated in Figure 7.1 below. The respondents were asked to revise the name of the second factor to **"Broad execution strategy"**, and the third factor to **"Certainty in planning"**.

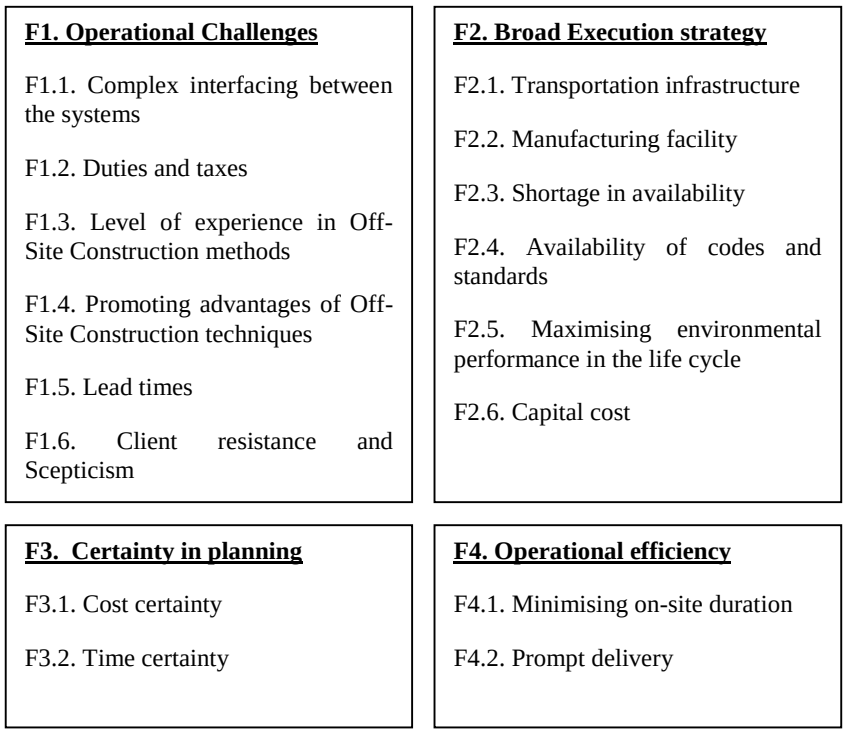


Figure 6.1. Constructs of the refined OSC readiness framework

6.5. Findings from the framework validation

In this stage, the researcher validated the framework through case studies. The case studies have assessed the practical applicability of the designed OSC readiness framework in the context of Indian construction organisations. The findings of the case study were discussed in the section below.

6.5.1 Organisation A

Table 6.2 Assessment of the Organisation A

Factors	***Level 1***	***Level 2***	***Level 3***
F1. Operational challenges			
F1.1. Complex interfacing between the systems			
F1.2. Duties and taxes			
F1.3. Level of experience in Off-Site Construction methods			
F1.4. Promoting advantages of Off-Site construction techniques			
F1.5. Lead times			

F1.6. Client resistance and scepticism			
F1.7. Guidance and information			
F2. Broad execution strategy			
F2.1. Transportation infrastructure			
F2.2. Manufacturing capacity			
F2.3. Shortage in local availability			
F2.4. Availability of codes / standards			
F2.5. Maximising environmental performance in the life cycle			
F2.6. Capital cost			
F3. Certainty in planning			
F3.1. Cost certainty			
F3.2. Time certainty			
F4. Operational efficiency			
F4.1. Minimising on-site duration			
F4.2. Prompt delivery			

The findings from the assessment of key factors affecting the Off-Site Construction readiness of Organisation A are illustrated in the above Table 6.2. The achieved maturity levels are represented by the highlighted yellow cells; whereas the blank cells illustrated that the organisation is yet to reach the maturity level. On the whole, Organisation A has achieved readiness level two in seven areas and level three in six areas. From this finding, it can be stated that the organisation A is well aware of OSC practices and is also partially incorporating OSC methods in the strategy. On the other hand, the organisation is still at level one in four areas.

In terms of the "Operational challenges" factor, the organisation has achieved third and second levels of readiness in three areas respectively. However, the organisation has only achieved level one in terms of level of experience in OSC methods, while the management prioritises staff training. Nonetheless, there is a standard practice of providing training to every new employee in the first month of their job. In addition to this practice, the management conducts staff training in their in-house learning academy before initiating on-site works in every project. A similar strategy has been proposed by Nadim and Goulding (2010) to provide adequate training and education to encourage people to accept and implement new methods of working. During the

site visit, the field supervisor mentioned that technical instructor was appointed in the previous project in order to assist the workforce in working with new and complex systems. The management ensures that the entire on-site workforce was provided with demonstrations and one to one sessions on working procedures. Though the organisation has an established policy on training, they did not customise a standard procedure for OSC projects.

This organisation predominantly uses locally available material and systems. The management has instructed the design and procurement teams to purchase all the material from local vendors. Regarding the expertise of staff, the HR manager reported during the interview that five of their current employees have more than seven years of experience in working in the OSC area. According to the HR manager, the organisation has a strategic approach towards recruitment. The management recruits the high number of candidates who completed diploma (ITI). Post-recruitment, the new joiners will be under apprenticeship. After training, the management selects candidates based on skill test, explaining why majority of the employees in the organisation A are only trained professionals without technical / academic qualification.

However, the manager stated that management is revisiting this recruitment approach and considering changing in order to balance the teams with experienced employees and new graduates. In addition, the organisation prioritised promotional activities in the strategy. According to the participants, the organisation participates extensively in annual exhibitions. It has also established collaboration with three government institutes in Visakhapatnam and Hyderabad. The management conducts an awareness programmes and lecturing sessions in the college of architecture, while the organisation maintains a calendar of academic and awareness programmes.

In addition, some of the staff write articles in the local newspapers about various advancements in the construction industry. Here, the researcher has identified success stories, details of landmark projects and award winning projects in the official website of the organisation. The organisation runs a fully equipped fabrication yard of 20,000 square meters in Visakhapatnam, Andhra Pradesh. During the interview, one of the senior project managers explained about this in-house manufacturing facility. In addition to this, the organisation also collaborated with

various stakeholders. Overall, the project co-ordinator stated that *"we always believe in mutual respect and trust and collaborative openness. The entire supply chain of our projects has high regards for our organisation"*. Another senior project manager explained that the design and engineering teams always work closely with the manufacturers and schedule the activities accordingly. In addition, the procurement team tracks the supply chain and delivery schedules. The in-house facility offers additional support. Hence, the organisation ensures that there are no delays to the activities on the critical path.

In the broad execution strategy, the organisation reached level one in three areas. Furthermore, it has attained level three in two sub-factors and level two in only one area. During the interview, the senior project manager informed us that the management is well aware of the prerequisites involved in the transportation of OSC products. As discussed earlier above, the organisation runs an in-house fabrication yard. Hence, the majority of the material is procured from this in-house facility or from the local vendors. The project manager shared that the procurement team schedules the delivery of material only in night time. In addition, the procurement team also documents the traffic guidelines of the recipient's city/area.

Furthermore, the project design and engineering team explained that they finalise the product selection and prepare all the estimation documents at the early stage of the project. The procurement and logistics team prepares a critical evaluation report of the potential manufacturers and vendors. The organisation is equipped with an in-house fabrication yard. In addition, the management awards the contracts based on the appraisal report and performance of the manufacturers. The project manager also shared that in the last six years, the management has repeatedly awarded contracts to four vendors based on their effective and prompt delivery.

In the interview, all the participants noted that shortage of materials and services is challenging the performance of the organisation. According to the senior project manager, the organisation's fabrication yard is manufacturing around the clock to meet demand. Despite the continuous efforts of the in-house facility and other associated manufacturers, the projects suffer from late delivery in some cases. In terms of maximising environmental performance in the life cycle, all the participants stated that they are aware of the off-site products with eco-friendly features.

However, they expressed collectively that the management does not prioritise the usage of these products.

In terms of planning certainty, the organisation has achieved level two in both the sub-factors. The organisation has placed the emphasis on cost effectiveness and adding competitive advantage to all their clients. The quantity surveyors' team and the procurement team have prepared the estimation and delivery schedules. The finance department also closely monitors the project actual cost and compares with the estimation. The management ensures critical planning of all projects. The procurement and supply chain department works on purchase orders, delivery schedules and the status of the material.

6.5.2. Organisation B

Table 6.3 Assessment of the Organisation B

Factor	***Level 1***	***Level 2***	***Level 3***
F1. Operational challenges			
F1.1. Complex interfacing between the systems			
F1.2. Duties and taxes			
F1.3. Level of experience in Off-Site Construction methods			
F1.4. Promoting advantages of Off-Site construction techniques			
F1.5. Lead times			
F1.6. Client resistance and scepticism			
F1.7. Guidance and information			
F2. Broad execution strategy			
F2.1. Transportation infrastructure			
F2.2. Manufacturing capacity			
F2.3. Shortage in local availability			
F2.4. Availability of codes / standards			
F2.5. Maximising environmental performance in the life cycle			
F2.6. Capital cost			
F3. Certainty in planning			
F3.1. Cost certainty			
F3.2. Time certainty			
F4. Operational efficiency			
F4.1. Minimising on-site duration			
F4.2. Prompt delivery			

The OSC readiness assessment results of Organisation B are provided in Table 6.3. During the process of the case study, the researcher conducted interviews and also visited one of the on-going projects being executed by the organisation. In addition to this, the researcher has also accessed the literature about the organisation available at the office and on their official website. On the whole, the organisation B has achieved readiness level two and level three in seven areas. It is at level one in only three areas. From this, it can be stated that the organisation B is well aware of OSC practices and is also prioritising the inclusion of OSC methods in the strategy.

In coming to these findings, the organisation has achieved third level readiness in four areas of the first key factor: "operational challenges". Organisation B has established standard practice in conducting training sessions and workshops on-site before erecting OSC products. According to the senior manager, the organisation has recruited skilled workforce for projects with an intense use of OSC products. During the site visit, the researcher observed some posters explaining the sequence of installation and safety measures on the walls of the site office. The management is committed to providing training and education on the working methods and assembling techniques of the OSC products. Such standard practices have enabled successful application of OSC products. **The researcher has noticed from the organisation's official website that they have remarkable success rate in completing several housing and public buildings (one airport) with a significant adoption of OSC techniques.**

The results against the operational challenges factor have indicated that the management has established a standard policy in the operations of all the OSC projects. Furthermore, the organisation is at level two in the readiness framework in terms of handling lead times, duties and taxes. During the interviews, the researcher identified the project planning and project management teams of Organisation B planned in co-ordination with the delivery schedules of the OSC products and other related services. However, the organisation has not collaborated with any of the manufacturers of OSC systems. In terms of "Information and Guidance", the organisation religiously follows the training and up-skilling of the workforce. The management have considered this as a priority in the vision document. It has also established a dedicated Research and Development (R&D) department. In addition

to the interviews, the researcher has also noticed the training schedule displayed on the notice board in the site office.

In terms of "Broad execution strategy", the organisation has demonstrated characteristic features of third level readiness only in the category of "transportation infrastructure". According to the findings from the interviews, the **project planning team evaluates the existing road and other connecting networks of any potential site at the initial stage of planning** of all the OSC projects**. In one of the previous project (international airport) they also requested that the manufacturers of OSC products submit the on-site and off-site transportation and manoeuvring plan.**

On the other hand, the organisation is at level two in the other three areas of broad execution strategy. The design and planning teams adhere to the standards provided by the manufacturers. In the interview, the project manager commented that *the imported products from Denmark and Germany possess detail guidelines and standards. But, we do not observe the similar practice from the local manufacturers.* The researcher has also found no evidence of such standards and code of practice during the site visit. However, the interview findings demonstrated that the organisation reached level two OSC readiness in terms of "availability of codes and standards".

The organisation's practices in the areas under broad execution strategy reflect that there is a frequent application of effective techniques in sub-factors, such as a manufacturing facility, for a successful implementation of OSC products. However, the management is yet to establish a standard policy and embed it in the organisation's strategy to achieve maximum advantages from the OSC projects. Furthermore, the organisation achieved only level one in addressing shortages in local availability and capital cost.

The Organisation B is at least at second level readiness in the factor "Certainty in planning". According to the interviews, the management is practicing measures and effectively implementing the cost and time planning tools in order to assure time completion within the planned budget. However, the participants expressed that there was no standard policy or guidelines in terms of practicing these applications.

Hence, the organisation might achieve third level OSC readiness if a standard procedure is embedded in the policy for applicability in all the OSC projects.

In the final factor, "operational efficiency", the organisation's OSC readiness can be assessed as beyond second level readiness. The organisation is at level two in terms of minimising on-site duration and has achieved third level readiness in maintaining prompt delivery in all the OSC projects.

6.5.3. Organisation C

Table 6.4 Assessment of the Organisation C

Factor	***Level 1***	***Level 2***	***Level 3***
F1. Operational challenges			
F1.1. Complex interfacing between the systems			
F1.2. Duties and taxes			
F1.3. Level of experience in Off-Site Construction methods			
F1.4. Promoting advantages of Off-Site construction techniques			
F1.5. Lead times			
F1.6. Client's resistance and scepticism			
F1.7. Guidance and information			
F2. Broad execution strategy			
F2.1. Transportation infrastructure			
F2.2. Manufacturing capacity			
F2.3. Shortage in local availability			
F2.4. Availability of codes / standards			
F2.5. Maximising environmental performance in the life cycle			
F2.6. Capital cost			
F3. Certainty in planning			
F3.1. Cost certainty			
F3.2. Time certainty			
F4. Operational efficiency			
F4.1. Minimising on-site duration			
F4.2. Prompt delivery			

The results of the OSC readiness assessment of Organisation C are documented in Table 6.4above. Here the yellow cells indicate the OSC readiness of the organisation in relation to the sub-factor. The blank or white cell shows that the organisation is yet to achieve this readiness level. Overall, Organisation C has achieved readiness level two in eight areas and level three in seven areas, although it only reached level one in two areas. The results have demonstrated that Organisation C is well aware of OSC practices and is also significantly incorporating OSC methods in the strategy.

Organisation C also achieved level two in the highest number of sub-factors under operational challenges. Meanwhile, the organisation reached second level readiness in five areas and third level readiness in two areas. Hence, it can be said that the organisation is significantly prepared for effective implementation of OSC products. During the interviews, the researcher found that the organisation conducts staff training and briefing sessions before executing work on-site. However, there is no standard practice of regular training. In previous projects, training and guidance were introduced as an immediate response to address on-site challenges. Moreover, the organisation only recruits staff when required. During the site visit, the researcher observed some charts with details of the project scheduling and health & safety measures.

In the broad execution strategy, the organisation reached level one, level two and level three in two areas. In the interview, the participants stated that they are aware of the special requirements involved in working with OSC products. However, the workforce did not contribute to the details of transportation planning in any of the previous projects. According to the project manager, the majority of the previous projects had appropriate accessibility and ample space in the site itself.

The management uses large cranes and other construction transportation equipment to deliver products to the actual work-place. The participants also shared that the procurement and logistics teams of the organisation work closely with the suppliers and manufacturers. The organisation maintains collaboration with some of the manufacturers and also ensures that all the manufacturers abide by the terms of the contract. The senior project manager shared one of the experiences derived from the previous projects. In one of the projects, the manufacturer of concrete slabs delayed

the delivery for inexcusable reasons. The management then penalised contractor and did not award them another new contact.

The organisation currently does not have any in-house facility. However, the senior project manager revealed that the management is considering establishing three manufacturing facilities. Furthermore, the organisation established affiliation and partnership with international construction companies for technical consultation and knowledge exchange. According to the senior project manager, this strategic partnership would strengthen the organisation in delivering efficient services and products. In the interview, the senior project manager expressed that the organisation is committed to increasing its green footprint. He also highlighted that sustainability is embedded in the vision document of the organisation. The participants reported that the organisation is constantly deploying new energy saving technologies in the operations. The organisation also successfully commissioned a "LEED GOLD" certified facility and a "LEED SILVER" certified facility. Furthermore, the participants also shared that the project teams has maintained the documentation of energy assessments and audits.

In terms of certainty in planning, Organisation C achieved second level readiness in cost certainty and third level in time certainty, demonstrating that the management is well aware of the advantages to be obtained from using OSC products in the context of time and cost. According to the participants, the management established a standard procedure in terms of cost planning and monitoring. The project manager explained that the organisation is aiming to achieve cost effectiveness. He also shared an example from one of their recent projects, where they completed the entire project under the planned estimation. The interviews highlighted that the organisation follows a standard project finance management system for all the projects. They applied the same method to the OSC projects; however, the research found that there is no customised policy for the needs of OSC projects.

On the positive side, the organisation embedded lean construction practices in its policies. This highlighted the organisation's commitment and approach towards achieving time certainty. According to the senior project manager, the organisation established a practice of submitting a 'Pre-construction Report' before starting the actual construction. This report presents execution, planning, scheduling, design

management, constructability review, bidding, logistics, risk analysis, MEP coordination, project reporting, value engineering, cost planning and controls of any project envisaged. According to the senior project manager, this report ensures that all the critical events are executed according the planned schedule. From the interview, it is evident that the organisation has an established policy to optimise performance.

In terms of operational efficiency, the organisation achieved third level readiness both in minimising on-site duration and prompt delivery. During the interview, the senior project manager explained that the management embedded lean practices in the organisation's policy document. The project management team effectively coordinates and ensures no deviation in executing all critical activities. They constantly monitor and incorporate any delayed activities into a fast-track project delivery schedule for successful and timely completion. In addition to this, the organisation also adopted a Modular Project Delivery (MPD) approach for OSC projects.

The interviewees also shared that the organisation maintains collaborations with local and international vendors. In addition, the management also performs supplier assessments and audits. The project manager explained that the supply chain management team issues the procurement specifications during the pre-construction phase. Furthermore, management awards contracts to reliable and efficient vendors based on assessment. According to the senior project manager, the organisation adopted this policy to achieve schedule optimisation. The organisation also developed and led a Modular Construction Technologies tour in order to identify the best vendors in the industry. This scheme reflects the fact that the organisation standardised the selection and awarding procedure for the OSC projects.

6.5.4. Summary

The summary of the findings from the three case studies are discussed in terms of each factors in the sections below.

6.5.4.1. OSC readiness in Operational challenges

All the three organisations have reached level two in terms of "Duties and taxes". Organisation B has achieved all the three levels of OSC readiness in more number of areas (4) in this context. It can be understood that, the organisation has established

standard policy for majority of the areas under this factor. Also, the organisation B can be regarded as more efficient in addressing the operational challenges during the execution of OSC projects. On the other hand, Organisation C has reached level two or above in all the areas of this factor. This demonstrates that the organisation has incorporated matured methods in planning and designing OSC products. The following table demonstrates the summary of findings in the area "operational challenges".

Table 6.5. Summary of findings in "F1. Operational challenges"

F1. Operational challenges			
Factor	**Org. A**	**Org. B**	**Org. C**
F1.1. Complex interfacing between the systems	Level - 2	Level - 3	Level – 2
F1.2. Duties and taxes	Level - 2	Level – 2	Level – 2
F1.3. Level of experience in Off-Site Construction methods	Level - 1	Level – 3	Level – 2
F1.4. Promoting advantages of Off-Site construction techniques	Level – 3	Level – 1	Level – 2
F1.5. Lead times	Level – 3	Level – 2	Level – 3
F1.6. Client resistance and scepticism	Level – 2	Level – 3	Level – 3
F1.7. Guidance and information	Level – 3	Level – 3	Level – 2

6.5.4.2. OSC readiness in Broad execution strategy

The researcher assessed the execution strategy of all the three organisations. During the interviews, all the participants from the entire sample have shared minimal to no knowledge on the area "capital cost". The researcher noticed that capital cost and investment details were not shared with majority of the technical and field staff. The senior project managers of different organisations have also disagreed to disclose the investment and finance details. This might be due to the sensible nature of the data.

Organisation A and C have standardised practices in two areas of the "broad execution strategy". However, out of the three organisations, Organisation A is only at level one in more number (3) of areas. The researcher demonstrated the findings in the table below.

Table 6.6. Summary of the findings in "F2. Broad execution strategy"

F2. Broad execution strategy			
Factor	**Org. A**	**Org. B**	**Org. C**
F2.1. Transportation infrastructure	Level – 2	Level – 3	Level –1
F2.2. Manufacturing capacity	Level – 3	Level – 2	Level – 2
F2.3. Shortage in local availability	Level – 1	Level – 1	Level – 3
F2.4. Availability of codes / standards	Level –3	Level – 2	Level – 2
F2.5. Maximising environmental performance in the life cycle	Level - 1	Level - 2	Level – 3
F2.6. Capital cost	Level - 1	Level – 1	Level – 1

6.5.4.3. OSC readiness in Certainty in planning

The researcher assessed the planning efficiency of the three organisations. According to the findings, organisation A has reached level two of the OSC readiness in both time planning and cost planning. On the other hand, the organisation B and C have achieved level three in terms of cost certainty and time certainty respectively.

Table 6.7. Summary of the findings in "F3. Certainty in planning"

F3. Certainty in planning			
Factor	**Org. A**	**Org. B**	**Org. C**
F3.1. Cost certainty	Level - 2	Level – 3	Level – 2
F3.2. Time certainty	Level - 2	Level – 2	Level – 3

6.5.4.4. OSC readiness in Operational efficiency

The OSC readiness framework was applied in all the three organisations to evaluate the operational efficiency. The findings demonstrated that all the organisations have achieved the third level of OSC readiness in "Prompt delivery". In addition, the Organisation C has achieved all the three levels in both the sub-factors.

Table 6.8. Summary of the findings in "F4. Operational efficiency"

F4. Operational efficiency			
Factor	**Org. A**	**Org. B**	**Org. C**
F4.1. Minimising on-site duration	Level - 2	Level – 2	Level – 3
F4.2. Prompt delivery	Level - 3	Level – 3	Level – 3

6.6. Chapter Summary

This chapter discussed the findings from the literature review, questionnaire survey, semi-structured interviews and case studies. From the literature, the researcher identified 27 influencing factors towards the adoption of OSC. A questionnaire tool was developed based on the findings of the literature. The questionnaire survey aimed to explore the extent of OSC practice in India. The survey revealed 26 key influencing factors. Further, the results also presented 14 drivers and 12 barriers that are affecting the uptake of OSC in India. Some of the drivers include, ensuring cost certainty and time certainty. In the next stage, the research developed a conceptual framework based on the literature review and data analysis of the questionnaire survey. The conceptual OSC readiness framework was further refined with the help of semi-structured interviews of the experts in field. After refinement, the proposed framework had four key areas, named operational challenges, broad execution strategy, certainty in planning and operational efficiency. In the final stage, the researcher tested the proposed OSC readiness framework in real life scenario to examine the applicability and adaptability of the framework. This chapter presented the design of framework, findings from the refinement validation processes. The validation process has shown that the OSC readiness framework has successfully assessed the level of OSC readiness of the organisation in all the three cases. The next chapter will present the conclusion of current research.

Chapter 7 | Conclusion

This chapter presents the conclusion to the thesis. In this chapter, the researcher summarises the research findings related to the research questions, obtained through the framework development and refinement (Chapter 4), and validation (Chapter 5) stages. The chapter also discusses the contribution of the research to the existing knowledge of Off-Site Construction and construction management and innovation.

The literature has documented that the construction industry is the second-largest industry in India. In recent years, the Indian economy has been growing at a rapid pace and the construction industry has been instrumental in accelerating this growth. According to the recent 'Make in India' campaign, the construction sector represents the second-highest inflow of foreign direct investment. However, India has an estimated housing shortage of about 19 million in urban area, and 47 million in rural area. Along with the housing shortage, the construction industry is also facing challenges in terms of a shortage of skilled workforce, and maintaining quality of construction within the time and cost estimations. Thus, the growth, rising demand for housing and infrastructure, along with sustainable goals and challenges, has encouraged the Indian construction industry to adopt alternative and advanced technologies. In this process, Off-Site Construction has evolved as a solution to achieve greater quality within the time and cost limitations in the construction industry. OSC has been observed as an effective alternative method in various countries. For instance, in the UK, Modern Methods of Construction (MMC) have been recommended as a means of handling the constraints carefully, in order to attain productivity and better quality.

The Government of India (GOI) has announced expansion of national highways and railway tracks compatible to run high speed bullet trains. The Finance Minister in his budget speech has promised to approve nearly 10,000 KMs of national highway in the year 2016-17. The total investment in the road sector by the government of India would be Rs. 97,000 crore (15,000M USD) during 2016-17 (Budget, 2016-17).

The growing urban needs necessitate construction of sky scrapping buildings etc. The urban transport infrastructure has been rapidly expanding including Metro rail, Bus Rapid Transport System (BRTS) and other services. All the infrastructure

projects need to be constructed with advanced technology and of high quality. Off site construction method is preferred to traditional construction practices by many provincial and the Union government. Some provincial governments are also building the weaker section housing colonies through Off-Site Construction techniques (Housing for all by 2022, Released in 2016).

Adding to this, new Greenfield airports and sea ports are also proposed in the future plan. The Sagarmala project for construction and development of ports has already been rolled out. GOI is planning to develop new green field ports both in the eastern and western coasts. The work on the National Waterways is also being expedited. In the civil aviation sector, the Government is drawing up an action plan for revival of un-served and underserved airports.

Real estate and ownership of dwelling is an important contributor to the Indian economy. It constituted 8.0 per cent of India's GVA in 2014-15 and grew to 9.1 per cent (Budget, 2015-16). It also generates significant income and employment owing to large forward and backward linkages through creation of demand in the input sectors and real estate services. The government also announced plans to build sixty million houses by the year 2022 under the 'Housing for All' scheme. That will cover the entire urban area consisting of 4041 towns with initial focus on 500 Class I cities and it will be implemented in three phases. As part of this scheme, 'A Technology Sub-mission under the Mission would be set up to facilitate adoption of modern, innovative and green technologies and building material for faster and quality construction of houses. That will also work on the following aspects: i) Design & Planning ii) Innovative technologies & materials iii) Green buildings using natural resources and iv) Earthquake and other disaster resistant technologies and designs.' Therefore, one can expect that the focus with regard to technology in Government Housing schemes would be on Offsite construction methods which are modern, innovative and of green technology.

For instance, Andhra Pradesh, the home state of the researcher was bifurcated into two in 2014 and has to construct its new capital for the residual state. In this background, the state interim secretariat building construction has been taken up in 45 acres (about20 hectares). Out of that, government buildings are coming up in 27 acres and 18 acres left for public facilities. The construction contract was finalized

on 20th February 2016. The work commenced in February and was completed by June, as targeted. Four departments have shifted their offices on 29th June 2016. Apparently, the completion time is a significant record in the recent history of India. The estimated cost of the project was 34.53 million US dollars. This Secretariat project is being built through Off-Site Construction methods to achieve speed and quality in construction. According to the government of Andhra Pradesh, this project has been achieving pace only due to the adoption of OSC techniques. Moreover, the interim state Assembly building was completed in a record time of 192 days (AP Budget 2017-18, Speech of Minister for Finance). Though, there are few other examples in India, these are unique government projects of prestigious nature.

This research has developed an Off-Site Construction readiness framework for Indian construction organisations. In the process, the researcher understood the concept of OSC techniques, and the advantages associated with its implementation. Further, the researcher also studied the driving forces and hindering factors affecting the successful adoption of OSC techniques. The chapter of this thesis presented a comprehensive discussion of the status and trends in practising OSC in various developed and developing countries.

Off-Site Construction has been considered as an efficient alternative in several countries in recent decades. This method functions as a trouble-shooter for various problems by addressing key issues in construction and infrastructure projects. The literature review demonstrated that the developed nations (for instance, the UK, US, Australia and Japan) have widely implemented these techniques, while developing nations are taking steps towards OSC in order to obtain competitive advantage in industry (Arif et al., 2012).

In the US, OSC techniques have been implemented since the beginning of the nineteenth century. The US housing industry has played a key role in the extensive use of OSC techniques (Lu, 2009). The same methods could be applied in the case of India. The Housing and Urban Development Corporation could extensively promote OSC techniques to address the rising demand for housing within the time and cost boundaries. The demand for sustainable construction in the US has given rise to the use of prefabrication in the construction industry. The Modular Building Institute (MBI) is the major organisation that deals with offsite construction in the US.

In the UK, many initiatives have been introduced to overcome the constraints in the construction industry. Modern Methods of Construction (MMC) was recommended to handle the constraints carefully, in order to attain productivity and better quality. Several researchers (Arif and Egbu, 2010; Blismas et. al., 2003; Goodier and Gibb, 2007; Vernikos et al., 2012) have considered OSC to be a potential solution for the problems in the UK construction industry. Organisations such as Buildoffsite and various academic and industry collaborations have been working closely with the construction industry to obtain maximum advantage through implementing OSC methods. The Australian construction industry identified OSC as a key solution to improve the industry (Blismas et al., 2006). It has prioritised OSC in the vision document developed for the bright future of the construction industry (Blismas and Wakefield, 2009).

Various studies have highlighted the scope of manufactured construction in different parts of China (Arif and Egbu, 2010; Jaillon and Poon, 2009; Jaillon and Poon, 2010). OSC is being considered as a solution to achieve greater sustainability, which is the main concern of the Chinese construction industry. The housing authority of Hong Kong intensified the adoption of prefabrication techniques in the mid-1980s (Chiang et al., 2006). Research by Jaillon and Poon (2008) discussed the achievement of a 52% waste reduction by implementing OSC techniques. This represents a noble example of achieving waste minimization through OSC. The construction industry in Malaysia and Singapore has identified Industrialised Building Systems (IBS) as a solution to address the issues associated with the foreign labour and sustainable development. It is evident that many countries have embraced OSC methods to achieve a sustainable built environment. The research has established that the use of Off-Site Construction has the potential to address some of the key government and industry demands for the construction sector in India.

7.1. Main research findings

The foundation of the research was as discussed in the first chapter, as follows: *Current research and literature on Off-Site Construction does not adequately assess the OSC readiness of construction organisations in India. Successful implementation of OSC highly depends on the readiness of the organisation. Hence, an OSC*

readiness framework would be influential for the initial assessment of OSC preparedness of construction organisations in India.

The research aimed to address four main research questions:

1. Are the Indian construction organisations aware of the offsite construction approach and its benefits? What is the current status of Off-Site Construction in India?

2. What factors drive and hinder construction organisations to pursue Off-Site Construction practices in India?

3. What is an Off-Site Construction readiness framework? What are the essential constructs of the framework? What are the advantages of the OSC readiness framework?

4. How ready are the organisations to adopt OSC techniques? How to evaluate an organisation's readiness to adopt OSC?

7.1.1. Current status of Off-Site Construction in India

The findings from the questionnaires, semi-structured interviews and case studies indicated that a significant proportion of construction organisations in India is aware of the OSC paradigm. Of the sample, 43.1% expressed that their organisation plans to increase the application of OSC in its future projects. It was also evident that the sample was well aware of the benefits associated with the OSC method. The research also identified that 69.1% (141 respondents) of the sample have used the OSC method to 'precast some components and cast the main structure on site'. According to the data, OSC is extensively used in the construction of factories, warehouses and industrial buildings. On the other hand, its application is less evident in private housing and educational institutions.

7.1.2. Drivers and barriers for Off-Site Construction techniques in India

The literature review presented various drivers and barriers identified by other researchers. According to Gibb (2001), the two fundamental drivers for Off-Site Construction are 'pragmatism' and 'perception'. Pragmatism was defined as 'industry response to an urgent need combined with lack of resource', and perception as 'client and public reaction to a prevailing design philosophy'.

Lusby-Taylor et al. (2004) highlighted speed in construction as a major driver for Off-Site Construction. In countries such as China and Malaysia, extensive promotion, incentives and a shortage in skills have encouraged OSC adoption (Arif & Egbu, 2010; Kamar et al., 2009). This shows that the influencing factors change according to the nature and working methods in respective countries. As Pan et al. (2007) mentioned, 'The response of the industry to an urgent need vary from country to country and over time'. Hence, the researcher investigated the drivers and barriers in the context of India.

The research identified that ensuring cost certainty and time certainty are major drivers towards the extensive adoption of OSC in India. Other encouraging factors for implementing OSC methods included speed of delivery, achieving high quality, reducing environmental impact and maximizing environmental performance in the life cycle. Regarding the barriers, respondents mentioned that a risk-averse culture, complex interfacing between the systems and a lack of local availability are some of the factors that hinder the extensive application and penetration of OSC in India. The drivers and barriers are:

Drivers

- Ensuring cost certainty
- Ensuring time certainty
- Speed of delivery
- Minimizing on-site duration
- Achieving high quality
- Addressing the skilled labour shortage
- Reducing health and safety risks
- Restricted site specifics
- Huge demand and delivery requirements
- Economy of scale
- Reducing environmental impact during construction
- Maximising environmental performance in the life cycle
- Few codes and standards available
- Skills shortage

Barriers

- Longer lead times
- Client resistance and scepticism
- Lack of guidance and information
- Negative image
- Not locally available
- No experience of its use
- Duties and taxes
- Complex interfacing between systems
- Risk-averse culture
- Lack of manufacturing capacity
- Lack of transportation infrastructure
- Higher capital cost

7.1.3. Off-Site Construction readiness framework and advantages

7.1.3.1. Off-Site Construction readiness framework

For the current research context, Off-Site Construction readiness can be defined as ‘a measure of the degree to which the organisation may be ready, prepared, or willing to obtain benefits which arise from the OSC practices’. This was developed based on the E- Readiness definition by Lou et al. (2008). The ultimate aim of the Off-Site Construction readiness framework is to investigate ‘how ready is the organisation to adopt OSC techniques in their current practice?’ The primary objective of the OSC readiness framework is to provide a reliable structure that could be used in practice before selecting OSC methods or at an early stage to assess the current readiness and improve the preparedness to achieve optimum advantage of OSC techniques. The results from the OSC readiness framework depict the extent to which the organisation is ready to adopt OSC technologies in various construction projects.

The researcher conducted an extensive study of the existing literature and identified 26 factors that influence the adoption of OSC. These 26 factors were presented in

the questionnaire survey, and respondents assigned the level of influence. The researcher then conducted factor analysis and obtained 17 key attributes. The main constructs of the OSC readiness framework are *Operational challenges, Broad execution strategy, Certainty in planning* and *Operational efficiency*. The operational challenges include factors such as complex interfacing between the systems, duties and taxes, level of experience in Off-Site Construction projects, promoting advantages of OSC techniques, lead times, client resistance and scepticism, and guidance and information. Similarly, transportation infrastructure, manufacturing capacity, shortage in local availability and availability of codes and standards are the factors in the broad execution strategy. The third key factor, certainty in planning, contains time certainty and cost certainty. The final key factor, operational efficiency, includes minimising on-site duration and ensuring prompt delivery. The OSC readiness of the organisation is defined in three maturity levels of the readiness framework. The level one represents no clear application, level two depicts frequent application – lack of standard practice, and level three demonstrates the highest readiness that is established operating procedure.

7.1.3.2. Advantages of OSC readiness framework

In view of the growing usage of OSC in construction industry, the OSC readiness framework will enhance and optimise the application of OSC techniques in the present global scenario. The potential advantages from the OSC readiness framework can be documented as follows:

- Accelerates effective implementation of OSC methods in the construction organisation;
- Enables the organisation to evaluate and benchmark its process in strategic, operational and completion phases;
- Provides scope to develop appropriate strategies for successful implementation of OSC methods;
- Enables the organisation to identify areas which require improvement or change.

7.1.4. Evaluation of OSC readiness of an organisation

The researcher conducted case studies in which the OSC readiness framework was assessed in a practical scenario. The 17 factors of the OSC readiness framework

were verified and validated by the case studies of three Indian construction organisations that were practising OSC methods. The results of the case studies confirmed that the OSC readiness framework can produce an assessment report, and that the organisations could improve in the areas where the readiness maturity level is low. The details of the case studies were discussed in Chapters 6 and 7.

7.2. Contribution to knowledge

The literature review has revealed a gap in the knowledge on OSC practices in India. It also noticed lack of readiness assessment tools in the area of OSC practices in general. There is no formal method of assessment to evaluate OSC readiness of the organisation. Therefore, exercising this research has helped to fill the gaps identified in the literature. The key contribution of this research is the creation of the Off-Site Construction readiness framework for OSC implementation at the organisation level. This developed and validated assessment framework will serve as a guide for OSC practitioners, policy makers and other key stakeholders involved in improving quality of the construction industry in any country.

Present research has made a significant contribution in two aspects of current knowledge. Primarily, the research established a set of 4 key areas that needs to be considered at the organisational level while implementing OSC in India. Secondly, the research developed the OSC readiness framework to assess the current level of readiness of the construction organisations. The data collected through the questionnaire survey, interviews and case study has provided robust information on the industrial perspective in India. The research will add to the existing knowledge on OSC in India by mapping issues relevant to the construction industry in India. The research has provided knowledge on the current status of OSC, the drivers and barriers affecting implementation of Off-Site Construction techniques in the Indian construction industry. The researcher has also documented the lessons learnt from the OSC-practising countries. The research has delivered leads for extensive academic research and managerial practice, as the adoption of OSC methods in India and OSC readiness assessment are critical to address the current demand and maintain quality output in the Indian construction industry. The outcomes of this research could also be used for some suitable awareness purposes in the Architectural, Engineering and Construction domains. In the real world implementation, the contribution of this research will reflect in the awareness and

the increase in confidence, and strength of organisations in the execution of OSC projects.

7.3 Future Area of Research

This research has contributed to the existing knowledge on Off-Site Construction practices in India. The framework developed evaluates the current readiness of any practicing construction organisation. However, the researcher has identified the need for further research. The scope for further research includes:

- The literature found that the shift from traditional methods of construction to OSC requires a robust strategy of integration and co-ordination of the work and schedules of the project from the inception till the completion. Hence, a detailed research on the strategy, focusing on the key events of the construction process is needed.
- The researcher found only limited research investigating current trends and practices of Off-Site Construction in India. Hence, further studies are needed focusing on strategies for successful implementation of OSC in India.
- The researcher identified that no Critical Success Factors (CSFs) are applicable to the case of India. The research experience from Malaysia has shown the importance of demonstrating the existence of CSFs in order to achieve optimal advantages from OSC practices. Therefore, future research is needed to identify CSFs in the Indian OSC domain.
- The OSC readiness framework proposed in this research will assess the readiness of the organisation in levels. Therefore, as part of future research, it is suggested to explore the level of importance of each readiness indicator by investigating the ranking and the impact of each readiness criteria on the implementation of OSC techniques.
- There is scope for more studies to be carried out to achieve optimum advantage of OSC in India. A research on developing OSC implementation guidelines and roadmap on OSC implementation in India can be done in future.
- The existing research in the sphere of Off-Site Construction models and road maps has significantly highlighted the prominence of the driving

factors in the context of people, process and technology. Current research has developed a framework based on the cumulative results of the data analysis. However, it has not covered the afore-mentioned dimensions of OSC. Hence, a detail study is needed to assess all the 17 indicators of the OSC readiness framework against each dimension. For instance, the indicators of operational challenges should be examined carefully in terms of people, process and technology. A similar study is needed for the other factors.

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Appendix

Appendix – A . Questionnaire Survey form

Questionnaire Survey Form

State of offsite practices in the construction industry, India

This questionnaire is being conducted as part of my Ph.D. research titled "Developing an offsite readiness model for Indian construction organisations". I am undertaking this research in the School of the Built Environment, University of Salford, United Kingdom.

The purpose of this questionnaire is to examine the current state of offsite construction in India. The data obtained from this survey will provide concrete information for further stages of my research where an "Offsite Readiness Model" will be developed to assess the offsite readiness of current construction organisations in India. Results from this survey also help in demonstrating the status quo of offsite construction in India.

Answering this questionnaire will take approximately 25 minutes. You are invited to participate in this questionnaire based on your experience in the construction sector. Your participation in this research study is VOLUNTARY. You may choose not to participate in this survey. You may withdraw at any time. Your responses will be confidential and all data will be used for ACADEMIC purposes only.

In this questionnaire, respondent's information, E-mail and organisation name are optional. No personal data will be disclosed.

If you have any questions about this questionnaire or research study, please do not hesitate to contact me at B.Deepthi@edu.salford.ac.uk

Please continue the questionnaire only if you VOLUNTARILY AGREE to participate.

1. Respondent's Information:

Name (Optional):

……

Email:

……

Company name (Optional):

……

Please tick the appropriate box for the following questions

2. What is the nature of the company you are working? (Please tick the appropriate box)

☐ Policy Maker/Government Official ☐ Developer ☐
☐ Manufacturer/Supplier ☐ Contractor
Architect/Engineer

3. What is your job title? (Please tick the appropriate box):

☐ Senior Manager ☐ Middle level Manager ☐
☐ Technical staff Administrative staff ☐ Others

4. How many years of experience do you have in the construction industry (Please tick the appropriate box):

☐ < 5 years ☐ 5 to 10 years ☐ 10 to 15 years ☐
>15 years

5. What are the main sub-sectors, in which your company is working? (select all that applicable)

☐ Public/Low cost housing ☐ Educational Institution

☐ Factories/ Warehouses/Industrial ☐ Restaurants/fast food ☐ Hotels/
☐ Leisure Supermarkets/Malls/Retails ☐ Private housing

☐ Public Buildings/ Office Buildings ☐ Hospitals/health

6. How many years of experience do you hold in offsite application in construction projects (Please tick the appropriate box):

☐ < 5 years ☐ 5 to 10 years ☐ 10 to 15 years ☐
>15 years

7. How many projects have you completed using offsite technologies? (Please tick the appropriate box):

☐ None ☐ 1-10 projects ☐ 11-20 projects ☐ 21-30 projects ☐ > 31 projects

8. How would you appraise the use of current Offsite applications in the construction industry?

☐ Very unsuccessful (1) ☐ Not good (2) ☐ Neutral (3) God ☐ (4) ☐ Excellent (5)

9. Does your company plan to increase the use of Offsite application in your future projects?

☐ Increase by ……..% ☐ Maintain same ☐ Decrease by ……%

10. What are the construction methods that are involved in offsite/ industrialized projects (Select all that applicable):

☐ Precast some components + Cast main structure on site

☐ Precast all components + Assemble on site

☐ Precast the whole house / building + Lift on site

Other:

11. Which types of precast structural systems are used in the involved industrialized projects (Select all that applicable):

☐ Steel ☐ Wooden ☐ Concrete ☐ Hybrid

12. Please rate the sub-sectors below, in terms of usage of offsite technologies:

Name of the sub-sector	**Very High Usage**	**High Usage**	**Average Usage**	**Low Usage**	**Very Low Usage**
Public/Low cost housing					
Private housing					
Office Buildings					
Hospitals/health					
Educational Institution					
Factories/ Warehouses/Industrial Buildings					
Public Buildings					
Hotels/ Leisure					
Restaurants/fast food					
Supermarkets/Malls/Retails					

13. What types of offsite/industrialized systems did you use or are planning to use:

Name of the system	Used in the past / currently using	considering using in the future	Not considering using for the future	Not aware
Load bearing wall panel				
Non- Load bearing wall panel				
Steel and concrete composite panel				
Cladding systems				
Precast frame				
Steel frame				
Precast floor and hollow core slab				
Panellised roofing systems				
Bath/ toilet/ kitchen pods				
Volumetric modular buildings				

Other (please write if not mentioned above):

14. In your view how are the offsite/industrialized techniques against the conventional on-site systems?

	Offsite techniques are				
Factor	**Significantly worse (1)**	**Worse (2)**	**Same (3)**	**Better (4)**	**Significantly better (5)**
Overall cost of construction					
Cost of transportation					
Cost of site erection					
Speed of construction					
Savings in raw materials					
Safety					
Unskilled labour requirement					
Expertise and experience needed					
Flexibility of design					
Equipment usage					
Logistics planning					
Ease of erection					
Final quality					
Rework and site problems					

15. In your opinion rate the advantages of offsite/industrialized techniques against the traditional techniques (Please rate on scale of 1 to 5)

Factor	Significantly less (1)	Less (2)	Same (3)	More (4)	Significantly more (5)

Decreased construction time					
Increased quality					
Reduced defects and waste					
Increased value					
Reduced Energy consumption and Pollution					
Reduced initial cost					
Reduced lifecycle cost					
Reduced onsite disruption					
Increased flexibility					
Greater customization options					
Ease of erection					
Ease of maintenance					
Ease of replacement					

16. Please rate the impact of the following factors on the uptake of offsite in construction industry? (On a scale 1 to 5 where 1 is strongly disagree and 5 is strongly agree)

Factor	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**	**Encourages the uptake of OSC**	**Discourages the uptake of OSC**
Ensuring cost certainty / Reliability in cost							
Ensuring time certainty							
Speed delivery							
Minimizing on-site duration							
Achieving high quality							
Addressing the skilled labour shortage							
Reducing health & safety risks							
Restricted site specifics							
Huge Demand and Delivery Requirements							
Reliability							
Economy of scale							
Reducing environmental impact during the construction							
Maximizing environmental							

performance in the lifecycle							
Longer lead times							
Client resistance & scepticism							
Lack of guidance and information							
Few codes/standards available							
Negative image							
Not locally available							
No experience of its use							
Duties and Taxes							
Complex interfacing between systems							
Risk averse culture Reluctance to change							
Skills shortage							
Lack of manufacturing capacity							
Lack of transportation infrastructure							
Higher capital cost							

17. What types of information is currently available on offsite/industrialized techniques?

Type of information	Widely available	Scarcely available	Not available
Successful case studies/best practices			
Technical manuals/designs			
General web resources			
Technical research reports			
Government and legislative sources			
Workshops / Training sessions			

18. Additional comments

Thank you for your time.

Appendix – B . Participant Invitation letter

(Interviews)

Dear Sir,

I am a current post graduate researcher in the School of the Built Environment, University of Salford. I am writing this to invite you to take part in my research project entitled: **Off-Site Construction readiness framework for Indian construction organisations**.

The purpose of this interview is to examine the newly developed assessment framework which will help in assessing the readiness of construction organisations to adopt Off-Site construction methods in India.

The interview is in a form of semi-structured questions. There are **no identified risks** from participating in this research and it is **completely voluntary**, and you may refuse to participate without consequence.

Attached to this invitation is a Participant Information Sheet. This will provide you with further information about the interview and who to contact if you have any questions.

I hope you choose to take part in this interview and to consider **sharing your experience**, which will help me identifying ways to improve the current state of Off-Site construction in India.

Thank you.

Sincerely yours,

Deepthi Bendi

Post graduate researcher,

School of the Built Environment

University of Salford

Salford, United Kingdom

Email : B.Deepthi@edu.salford.ac.uk

Signed

[……]

Appendix – C . Participant information Sheet

Development of Off-Site Construction readiness framework for Indian construction organisations

What is the purpose of the study?

The purpose of this interview is to validate the newly developed framework to assess the readiness of construction organisations to adopt Off-Site construction methods in India.

Why have I been invited?

You have been invited to participate in this research as you are an effective contributor to Indian construction industry.

Do I have to take part?

It is really appreciated if you participate and you are free to withdraw at any time, without giving a reason.

What will happen to me if I take part?

- Your identity remains **anonymous** and **confidential**.
- All publications of data will be written in a way so as to cover your identity.
- Data will be stored in a secured PC and then will be destroyed when it's no more needed.

What will I have to do?

You will be asked to sign a consent form to show that you agreed to take part. This will be provided at the time of interview.

What if there is a problem?

If you have a concern about any aspect of this study, you may speak to me; I will do my best to answer your questions.

Will my taking part in the study be kept confidential?

- All information which is collected about you during the course of the research **will be kept strictly confidential**, and any information about you which leaves your organisation will have **your name and address removed** so that you cannot be recognised.
- Collected data will be stored electronically on a password protected computer, accessed only by me.
- Procedures for handling, processing, storage and destruction of data match the principles in the Data Protection Act 1998.
- Collected data will be stored and archived. After that, data will be deleted.

What will happen if I don't carry on with the study?

If you withdraw from the study all the information and data collected from you, to date,

will be destroyed and your name removed from all the study files

What will happen to the results of the research study?

The results of the study in which you are involved in, will be made available on your request.

Further information and contact details:

Deepthi Bendi

Post graduate researcher,

School of the Built Environment

University of Salford

Salford, United Kingdom

Email : B.Deepthi@edu.salford.ac.uk

Thank you.

Sincerely,

Deepthi Bendi

Signed

[……]

Appendix – D . Questions for the semi structured interview

Questions for the semi-structured interview to refine the Off-Site Construction readiness framework

1. What do you think about the factor groups within the framework? Are the components related to the factor assigned?

2. Are factor definitions clear to you?

3. What do you think of the maturity levels content for each factor?

4. Are the three maturity levels enough to assess the off-site readiness of construction organisation in India? If not, how many maturity levels do you suggest?

5. Is the framework easy to understand in terms of assessing the Off-Site readiness within the organisations? If not, which part you didn't understand and what do you suggest?

6. Do you have additional comments about the framework?

		Ensuring cost certainty / Reliability in cost	Ensuring time certainty	Speed delivery	Minimizing on-site duration	Longer lead times	Client resistance & scepticism	Lack of guidance and information	Few codes/standards available	Maximizing environmental performance during the life cycle	Not locally available	No experience of its use	Duties and Taxes	Complex interfacing between systems	Risk averse culture	Lack of manufacturing capacity	Lack of transportation infrastructure	Higher capital cost
Correlation	Ensuring cost certainty / Reliability in cost	1	0.335	0.179	0.009	-0.142	-0.138	-0.145	-0.013	-0.015	-0.047	-0.037	-0.113	-0.05	-0.21	-0.138	-0.072	-0.094
	Ensuring time certainty	0.335	1	0.439	0.118	-0.153	-0.206	-0.191	-0.171	-0.287	-0.183	-0.149	-0.208	-0.133	-0.242	-0.315	-0.135	-0.208
	Speed delivery	0.179	0.439	1	0.346	-0.145	-0.284	-0.173	-0.103	-0.3	-0.092	-0.103	-0.147	-0.089	-0.264	-0.145	-0.086	-0.155
	Minimizing on-site duration	0.009	0.118	0.346	1	-0.039	-0.202	-0.106	-0.158	-0.277	-0.136	-0.138	-0.184	-0.053	-0.126	-0.126	-0.155	-0.162
	Longer lead times	-0.142	-0.153	-0.145	-0.039	1	0.385	0.305	0.254	0.354	0.352	0.366	0.396	0.345	0.371	0.302	0.287	0.364
	Client resistance & scepticism	-0.138	-0.206	-0.284	-0.202	0.385	1	0.519	0.422	0.418	0.467	0.462	0.39	0.416	0.423	0.281	0.443	0.399
	Lack of guidance and information	-0.145	-0.191	-0.173	-0.106	0.305	0.519	1	0.525	0.433	0.395	0.401	0.396	0.441	0.433	0.355	0.412	0.439
	Few codes/standards available	-0.013	-0.171	-0.103	-0.158	0.254	0.422	0.525	1	0.529	0.361	0.402	0.46	0.447	0.416	0.467	0.394	0.458
	Maximizing environmental	-	-0.28	-0.3	-0.277	0.3	0.418	0.433	0.529	1	0.47	0.362	0.4	0.468	0.4	0.438	0.419	0.5

	performance during the life cycle	0.015	7			54					3		33		51			27
	Not locally available	-0.047	-0.183	-0.092	-0.136	0.352	0.467	0.395	0.361	0.473	1	0.325	0.298	0.427	0.419	0.398	0.424	0.382
	No experience of its use	-0.037	-0.149	-0.103	-0.138	0.366	0.462	0.401	0.402	0.362	0.325	1	0.437	0.447	0.388	0.335	0.317	0.438
	Duties and Taxes	-0.113	-0.208	-0.147	-0.184	0.396	0.39	0.396	0.46	0.433	0.298	0.437	1	0.459	0.329	0.318	0.236	0.43
	Complex interfacing between systems	-0.05	-0.133	-0.089	-0.053	0.345	0.416	0.441	0.447	0.468	0.427	0.447	0.459	1	0.452	0.343	0.275	0.436
	Risk averse culture	-0.21	-0.242	-0.264	-0.126	0.371	0.423	0.433	0.416	0.451	0.419	0.388	0.329	0.452	1	0.311	0.243	0.392
	Lack of manufacturing capacity	-0.138	-0.315	-0.145	-0.126	0.302	0.281	0.355	0.467	0.438	0.398	0.335	0.318	0.343	0.311	1	0.383	0.355
	Lack of transportation infrastructure	-0.072	-0.135	-0.086	-0.155	0.287	0.443	0.412	0.394	0.419	0.424	0.317	0.236	0.275	0.243	0.383	1	0.507
	Higher capital cost	-0.094	-0.208	-0.155	-0.162	0.364	0.399	0.439	0.458	0.527	0.382	0.438	0.43	0.436	0.392	0.355	0.507	1

Appendix – E . Correlation Matrix