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Uptake of Off-site Construction: Benefit and Future Application

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***Abstract*—**Off-site construction methods have played an important role in the construction sector in the past few decades. It is increasingly becoming a major alternative technique and strategic direction compared to traditional in-situ method. It produces a significant amount of value for the construction industry and the economy more generally. To date, an impressive number of studies have been lunched on the perceived perception of off-site construction. However, it seems that a quantifying benefit on the offsite construction area is lacking. Therefore, this paper examines the recent research literature on the benefits of off- site construction and provides future direction. In the beginning, this paper provides a brief history and current value of the off-site construction followed by a detailed discussion on the benefit of off-site construction. These benefits include but not limited to time saving, quality improvement, relieving skills shortages, cost reduction and productivity improvement. Toward this end, off-site construction should learn from other productive industry similar to services or manufacturing industry by applying operational management tools and techniques with extensive focus on employee empowerment will shed the light on future uptake of Off-site construction. This study is of value in providing scholars have a clear picture of perceived benefit of off-site construction research and give an opportunities for future uptake of off-site method.

***Keywords*—**Building projects, Employer empowerment, Off-site construction benefits, Productivity.

I. Introduction

OVER the past few decades, the construction sector in several nations has experienced poor performance and low productivity [1]. The labour-intensive natures of the industry and shrinking levels of professional skills and craftsmanship have been key factors hampering productivity growth [2]-[4]. As a way forward in resolving the problem of productivity limitations to traditional on-site construction has been the introduction of off-site construction methods such as prefabrication and modularisation with a view to increase efficiency and standardise the management of quality [5].

A main reason for industry's endorsement of off-site production methods has been a perceived improvement in productivity [6]; indeed [3] shows off-site production (fabrication of sub-element components) has resulted in an efficiency gain of up to 40% per employee. While there has been a substantial body of research which has focussed on the *perceived* benefits of construction projects, there has been relatively little empirical evidence of real benefits vis-à-vis traditional on-site construction. Offsite construction seen from most of the construction literature as an alternative for traditional in-situ method and new researcher area, given that literature review as a key methodology in examining the development of offsite construction research discipline [7]. These literature researches do not only examine the advantages of offsite construction, but also help them explore new and valuable research topics for future uptake of offsite construction.

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II. Offsite Construction

Off-site construction, in lieu of in-situ approach, might be a way forward for undertaking productivity issues in building; broadly speaking off-site construction is where sub- elements are constructed remotely then transferred to and installed on site, as distinguished from in situ methods built directly on site [5]. References [8], [9] refer off- site construction into four classifications:

1) Component manufacture and sub-assembly such as door, furniture and light fittings.
2) Non-volumetric pre-assembly (those units that do not enclose usable space, e.g. wall panels).
3) Volumetric pre-assembly (those units that enclose usable space).
4) Modular buildings (units that themselves form usable buildings with only minimal work left to be accomplished on- site).

III. Offsite Construction Historical Background

As [10] points out, the use of manufactured buildings is not a new phenomenon. In the 1830s, John Manning created a portable colonial cottage and there were several other examples of off-site production throughout the 19th century. Reference [11] interestingly points out that prefabricated houses were used during the process of colonial expansion by European nations, given that there was a demand for 'European-style housing' and using local labour and materials was not favoured. Prefabricated hospitals were also used during the Crimean War, while the Industrial Revolution led to the 'industrialised building method' coming into fashion, leading to the use of prefabricated cast-iron buildings [11].

After the Second World War, off-site construction began to be utilised on an even larger scale. The population growth following the Second World War led to a demand for new housing, and prefabrication was seen as an effective way of catering for this demand. In particular, the rise of the welfare state in the Western world led to a boom in public housing. Prefabricated units were ideal for this purpose due to their

standardised approach, which at the time was culturally valued due to its ordered nature [12]. Prefabrication was also popular due to the economies of scale which could be generated from standardised mass production [13].

Towards the end of the 20th century, off-site construction began to be used in a more diversified range of areas, such as hotels, schools, hospitals and prison buildings. As societies have become wealthier and demand for 'welfarist' public projects have declined, pre-fabrication is being increasingly reallocated to commercial projects such as airport developments, hotels, MUZZ BUZZ drive a way, petrol station outlets and a range of retail hubs that use uniform repetitive designs & specification. However, [8] mentions that some rapidly developing countries currently have housing needs similar or exceeding those of the Western world after the Second World War, and that off-site construction has yet again become a way of addressing these needs and providing cheap standardised housing for large numbers of people. Indeed develop nations such as Germany and Japan have, through their development retained an inclination towards off-site residential works.

According to [8], the history of off-site construction is one that 'waxes and wanes'. Thus, rather than seeing off-site construction as an emerging trend that represents a sort of teleological progress, it may be more useful to perceive it a cyclical phenomenon. Off-site construction is on the upswing in periods when its inherent advantages (or perhaps its *perceived* advantages) are more useful. At other times, it may fall out of fashion. As [8], [13] point out; perception of off-site construction is a key predictor that influences its use throughout history. In turn, perception is heavily influenced by social, cultural and economic contexts. While these are beyond the scope of this paper, it is important to keep this in mind when thinking about the deeper reasons why off-site construction is valued in some time periods and for some uses but not in others.

IV. Offsite Construction Current Adoption and Value

Off-site construction methods have played an increasing role in the construction sector in the past few decades. In the United Kingdom, a greater use of off-site methods such as pre-fabrication was recommended in the Egan Report [14] as a way of boosting the productivity of the construction industry. It was also recommended by the Housing Forum Report [15] as a way of overcoming the shortage of skilled labour in the on-site construction sector and improving the quality of housing in a cost-effective manner. Studies and reports in several other countries have recommended greater adoption of off-site construction, including in Australia [16].

Off-site construction produces a significant amount of value for the construction industry and the economy more generally. Reference [10] conducted a comprehensive study of the value of the off-site construction industry in the United Kingdom. He found that, in 2008, the total gross output of the off-site construction sector was approximately £5.8 billion. This represented a substantial rise from 1998, when it was £2.3 billion [10]. According to [10], a more appropriate measure than gross output is value-added, since it indicates the contribution that off-site construction makes to gross domestic product (GDP). The total value added of the sector rose from £731 million in 1998 to £1.537 billion in 2008, more than doubling in value.

It is important to note, however, that the overall share of off-site construction in the construction sector remains low. According to [17], off-site construction only makes up 2.1 per cent of the total value of the UK construction sector. Furthermore, the financial crisis that began in 2008 affected the sector deeply. Value added was £2.08 billion in 2007, representing the high point in the past decade, before it declined back to £1.537 million in 2008, a value that was below 2004 levels [10].

It is unknown whether the trends found in [10] can be applied to other countries, including Australia. In particular, it would be interested to see whether Australia's off-site construction industry was affected by the global financial crisis to the same extent as the United Kingdom. It is likely that, due to Australia's relatively more robust economy in the past few years, the off-site construction sector here has not suffered the same decline since 2008. Nevertheless, it is also possible that the sector did not experience the same amount of growth as the UK sector did in the early 2000s certainly whilst in-situ brick and block still dominates domestic Australian market, prefabrication and "tilt-up" construction has begun to be seen as very important in the proving of ware housing& less complex structures and venues.

According to [13], the uptake of off-site construction is partly influenced by the perception that key players have of the advantages of off-site construction. Thus, the next section of this paper will discuss the perceived benefits, with reference to several studies in this area.

V. Offsite Construction Benefits

Off-site construction can bring about several benefits to the construction process. Indeed, it was identified in the seminal Egan Report [14] in the United Kingdom as playing an important role in improving performance in the construction industry, which suffers from low productivity. While there has been a substantial body of research which has focussed on the *perceived* benefits of construction projects, there has been relatively little empirical evidence of real benefits vis-à-vis traditional on-site construction. Indeed, [18], [19] note that evaluations of off-site construction are largely grounded in anecdotal evidence rather than rigorous data. More recently, [19] states that there is a lack of research that objectively measures the benefits of off-site construction; instead, most research has focused on case studies or subjective studies on experiences with off-site construction.

Nevertheless, research on perceived benefits is useful for two reasons: First, because it provides a benchmark to measuring the actual performance of off-site construction. It enables one to ascertain whether the perception is empirically valid and provides a good starting point for any empirical research. Second, because knowing about how various groups

perceive the benefits of off-site construction is itself beneficial; it is, after all, these groups that drive adoption of off-site construction, and to this end, perceived benefits may be more important to determining the future of the industry than real benefits. In particular, it is useful to look at the benefits that off-site construction provides from the perspective of key stakeholders in the construction process, such as clients, designers, contractors and building companies. This then provides the foundation of a need to establish explicitly and empirically the extent to which off-site manufacturing can provide a benefit and more importantly the *variables that need to be identified to measure and record and improve upon existing prefabrication techniques*. The benefits of offsite construction in a general view have been widely recognised [7], [20], [21]. In the following section the authors present the perceived benefit of off-site construction.

A. Time Saving

The most significant benefit of off-site construction is the time savings that it brings about. By transferring a significant proportion of the construction work to an off-site facility, the time spent on-site is reduced. The more predictable conditions of the factory and the economies of scale that they generate can also ensure that construction deadlines are met more effectively than in a traditional on-site environment. Reference [9] interviewed senior personnel from the largest construction clients in the United Kingdom of their opinions towards pre-assembly, one of the main forms of off-site construction. Over 40 per cent of all responses chose time/speed as the main reason for choosing off-site construction. Pre-assembly enabled less time to be spent on site and a reduction in commercial *risk* as a result of faster time frames for projects.

In another British study of clients, [22] found time to be the greatest advantage of off-site construction methods: 87 per cent of clients and designers listed it as an advantage, with 38 per cent placing it as greatest advantage. Contractors perceived time to be an even greater benefit arising from off-site construction, with 68 per cent placing it as their first choice [22]. This is supported by [23] who interviewed both general contractors and designers (architects and engineers) in the United States. Among contractors, the most frequent reported benefit of off-site construction was the reduction in overall project schedule and the reduction in construction duration, both of which are related to time. Together, these two benefits were reported by 64 per cent of the surveyed group as part of their top three reasons for using off-site construction techniques. In a study of house building companies in the United Kingdom, ensuring time certainty was cited by 54 per cent of respondents as a driver for using off-site construction methods [24]. Reference [13] studied the perception of off-site manufacturers and found that a reduction in on-site assembly time was one of the main benefits which they felt that off-site methods had over traditional methods. Finally, in [25], shorter project time scales were held to be the main benefit of off-site construction methods.

B. Quality Improvement

Another significant benefit cited by all stakeholders was quality improvement. The main advantage of off-site construction in this regard is that it enables a tighter control over quality than an on-site environment. Reference [13] found that quality of production and finish was the single most important perceived benefit of off-site construction over traditional on-site construction. Reference [9] discovered a perception among clients that elements made off-site, in a factory, were more consistent and had gone through a greater degree of quality control and testing than elements made on-site. Less time spent on snagging (remedial works) was also mentioned as a benefit. Overall, the study found that quality was the second most significant factor reported by clients for choosing off-site construction. Reference [22] found increased quality to be the second most significant benefit of off-site construction methods: 28 per cent of clients and designers cited it as their first choice, while 15 per cent of contractors did the same.

In [23], the increase in quality was not ranked as highly: it was only the four most common response among designers and the seventh most common among contractors. In [24], quality was ranked fourth among house building companies among relevant factors, with 50 per cent holding that it was a driver for them adopting the use of off-site methods. It is unknown whether the discrepancies between these two surveys and those of [9], [22] are significant or merely the result of survey variance.

Reference [8] states a key quality benefit of off-site construction is its potential for continuous improvement and quality management over time. Due to standardisation, modules constructed off-site can be continuously improved as time goes by, something which cannot be done with the ‘one-off, unique project approach’ in traditional on-site construction. This is significant for this study in that given industries more towards *continuous improvement* globally (Bectel and others dominant players) there are *opportunities* to seek future improvement through the application of operational management (total quality management) tools and techniques towards *measurement* of current and improvement of future efficiency.

C. Addresses Skills Shortages

A third major factor behind stakeholders favouring off-site construction was the fact that it relieves skills shortages in the construction industry. Off-site construction essentially enables the construction process to be ‘outsourced’ to another environment, requiring less labour to be invested into traditional on-site processes and addressing the shortage in this area. Indeed, Reference [24] found this to be the single most important driver for the adoption of off-site construction methods among British house building companies. 61 per cent cited it as a driving force in this regard. While not as significant as in the case of building companies, compensating for the skill shortage of craft workers remained within the top six reasons for general contractors using off-site construction [23]. Western Australia currently recognises such as skill

shortage and is actively involved in recruitment strategies as well as apprentice schemes to address this problem.

Interestingly, from a developed European standpoint, [9] found this to be a minor reason in their study of clients: less than 10 out of 117 unprompted responses mentioned 'people'-related reasons, which included the lack of skilled labour and the fact that off-site construction meant that there were fewer people on site. This discrepancy may arise from the fact that, in comparison to contractors and building companies, clients have less awareness of the dynamics of the construction industry and the skill shortage problems within it. Indeed, [9] points out that the clients are less likely to understand the benefits and disadvantages of off-site construction methods in comparison to other stakeholders. As such, they may be more likely to favour off-site construction for 'visible' reasons such as shorter time frames and higher quality. Another problem might be the fact that, according to [9], off-site construction itself suffers from supply shortages. Lack of availability was the third highest reason why building companies did *not* use pre-assembly methods of off-site construction. This is supported by [22]; where only about 40 per cent of off-site suppliers interviewed felt that supply was enough to meet demand for off-site construction.

D.Cost Reduction

The fourth perceived benefit of off-site construction is cost saving. It was cited to be a major advantage in several surveys but has also been listed as quite high in its initial cost. According to [24], the improved cost *certainty* of off-site construction was a major driver for its use by house building companies. This may be explained by the fact that off-site construction is more predictable and less likely to suffer from cost blowouts caused by unknown factors such as the weather. Among architects and engineers, the *reduction* of overall project cost was the second most frequent response for using off-site techniques, raised by 36 per cent of respondents [23]. In [9], cost was cited as the third most important benefit by clients. The key focus in the responses was on the fact that off-site construction could lead to lower cost, even though some responses also mentioned the increased cost certainty of off-site methods.

In Addition, 'many of the benefits [of standardisation and pre-assembly] are realised elsewhere in the construction process', such as through reduced labour on-site [8]. Reference [22] makes a similar point when they note that other benefits of off-site construction, such as better quality and reduced remedial work, are often not included in costings. For instance, [26] shows that the cost of maintaining off-site bathroom modules can often be as low as one-third those of bathrooms constructed on site. This 'life cycle cost' across an assets usable life being an often overlooked aspect for an industry that emphasises initial capital costs predominantly. Reference [27] similarly notes that the main advantages of off-site production are not direct, but rather come from indirect cost savings and non-cost value-adding items. As a result, while initial costs may appear higher, the actual cost of off-site construction methods (particularly over the whole life of the project) may be cheaper than the use of traditional on-site methods.

E. Productivity Improvement

The concept of productivity provides another way of conceptualising the benefits of off-site productions. Some studies, such as [9] mentions productivity gains as a distinct category – in their study of construction clients, productivity is cited as the fourth most important benefit of off-site construction methods. Nevertheless, only slightly more than 15 per cent of respondents listed productivity as their main reason for choosing off-site construction.

However, a broader view indicates that greater productivity can be viewed as the overriding benefit of off-site construction, with the reduced time, higher quality and lower cost of projects ultimately meaning that the process is more productive per unit of input than on-site construction. Indeed, the work proposed by this study has, as one of its aims a structured means and method to *identify* and *measure* the *variables* of productivity objectively.

VI. Future Recommendations

Towards this end a greater focus on *objective* research on the *identification*, *measurement* and *monitoring* of the *variables* that differentiate off-site construction, from more traditional in situ supply and installations activities which can then be used to guide industry in the off-site methods can add value to a project and in particular seek to address explicitly *performance variables*. As pointed out previously and noted by [19], while there is a significant body of literature on case studies and stakeholder perceptions of off-site construction, there is little *objective* comparison between it and off-site construction and more importantly that *objectively* clarifies *performance variables identification* and *measurement* in off-site work. In particular, as [13] states, more research needs to be carried out to assess the cost of off-site construction relative to on-site construction; in other words *performance factors*. Reference [19] states that more research should be conducted into how manufacturing principles from other industries, such as steel, chemicals and machinery, can be applied to the construction industry. They note that principles from other manufacturing industries have successfully been applied to off-site construction of homes in Japan. This point, which is often ignored, is a highly valuable one. Insights from more established manufacturing industries and their means to *measure performance* through *operational management* can ensure that off-site construction, a relatively young and local industry, has opportunities to develop perhaps in an efficient and *productive* way. This would add value to guidance in the utilisation of off-site construction. In other word, assessing productivity of off-site construction with reference to operational management and employee empowerment should be a focus arena for future academic research in off-site construction. A main focus seeks to identify factors affecting the productivity of off-site construction industry in specific areas such as prefabrication; a future goal is to measure empirically the current productivity of off-site construction

industry fabrication methods relative to traditional *in-situ* methods.

Despite the promise offered some advocates of off-site construction methods, [8] notes that a total or even predominant switch to standardisation and prefabrication is untenable. Instead, he argues that the focus should be on optimisation rather than maximisation of use [8] Similarly, [13] states that off-site construction 'is not, and is unlikely to become, a universal construction solution for all built assets. Instead, stakeholders should focus on determining the *appropriate* use of off-site construction, finding areas where the advantages of off-site construction can add the most value and where opportunities for continuous improvement exist. For example, off-site construction, due to its more precise and fast time frames, may add a lot of value to projects that need a more standardised and uniform design solution to a repetitive (non-complex) design brief, to be completed by a fixed time, but may not be so useful in circumstances where this is not an important factor.

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