Prefabrication in Hong Kong's High-Rise Residential Construction: Evolution and Effect on Waste Minimization

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Abstract. Managing construction waste efficiently to minimize its irreversible harm to the surrounding environment has been a long-standing issue plaguing various economies around the globe. Against such backdrop, prefabrication as a green building technology capable of reducing construction waste at source has been increasingly advocated by governments worldwide during the past two decades. By using statistical analyses (e.g. comparison of percentages, independent samples t-test) supplemented by an interview to analyse a valuable secondary dataset on 90 residential projects, this study aims at understanding the trend of prefabrication in Hong Kong, comparing the waste management performance between conventional and prefabrication projects, and uncovering the type(s) of precast component(s) most conducive to waste minimization in residential developments. This study uncovers the reasons behind the decline in popularity of certain precast components in private residential projects, and that incorporating greater levels of precast window and wall components would contribute to reducing waste generation in residential projects. The findings presented in this paper contributes to the understanding of the status quo of prefabrication adoption in residential projects of Hong Kong, which serves as a reference for the government's formulation of policies promoting precast construction.

Keywords: Construction waste · Prefabrication · Waste management performance · Waste minimization · Hong Kong

1 Introduction

Construction waste, also known as construction and demolition (C&D) waste, refers to waste materials generated by various kinds of construction activities, including but not limited to building works, demolition and maintenance [1]. It commonly includes debris, broken concrete, soil, timber, bamboo, and packaging waste [2]. Construction waste, if not properly managed, can inflict irreversible harm to the environment, including soil, air, water, and waste pollution [3, 4]. The significant environmental impacts arising from construction waste has caused the development of innovative waste management approaches to become the top of various governments' agenda.

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Being a green building technology increasingly advocated by governments around the globe during the past two decades, prefabrication has been widely recognized as a means to alleviate the adverse impacts posed by construction activities to the environment. Contrary to conventional cast-in-situ construction, prefabrication involves manufacturing building components at a location other than the construction site (normally a factory environment) before transporting to the construction site for final assembly [5, 6]. By minimizing on-site wet trades such as painting and tiling, as well as timber formwork waste [7], precast construction has long been perceived as conducive to reducing onsite construction waste.

As a coastal city situated in the Southern part of China plagued with the long-standing issue of land shortage, Hong Kong has no room for opening up new landfills [8]. At the turn of the 21st century, construction waste had already constituted a considerable proportion of this city's landfilled waste. It is against such background that the government of Hong Kong had begun to promote the adoption of precast construction in building developments by introducing various initiatives. The provision of gross floor area (GFA) exemptions for developments with bay windows and non-structural prefabricated external walls were two of the most remarkable incentives.

Over the years, an array of academic research examining the effect of prefabrication on waste management performance, which is usually measured in terms of waste reduction percentage, have been undertaken. Nevertheless, most of them have relied on qualitative data collected by ethnographic methods such as interviews where accuracy might be hampered by respondents' memory loss. Furthermore, they tended to cover samples comprising different types of projects rather than exploring a specific project type. To address the limitations of existing studies, by using a valuable secondary dataset compiled with reference to the databases of several government departments, this study aims at achieving three research objectives: (1) to understand the trend of prefabrication adoption in public and private residential projects; (2) to explore the difference in waste management performance between prefabrication and conventional residential projects; and (3) to identify category(ies) of precast components most conducive to construction waste minimization (if any). Following this introduction, Sect. 2 provides an overview of prefabrication adoption in high-rise construction and a review of past studies exploring the effect of prefabrication on waste minimization. Section 3 explains the research methods. Section 4 reports on the data analyses, results and findings. The implications of the key findings and relevant policy recommendations are being discussed in Sect. 5. Lastly, conclusions are drawn in Sect. 6.

2 Literature Review

2.1 Overview of Prefabrication Adoption in High-Rise Construction

Prefabrication means transferring certain proportion of construction works from the building sites to factories or other manufacturing sites where mass production of building components is allowed [9]. In practice, prefabrication can either be carried out on-site or off-site. On-site prefabrication refers to the casting of building components on the construction site or in a temporary production facility in the vicinity of the site [10, 11]. Contrarily, off-site prefabrication is the case where building components are being manufactured in areas remote from the construction site, usually under a factory environment, before they are being transported to the site for installation at their final position [12]. As a compact city plagued with land shortage [13], Hong Kong has long been employing off-site prefabrication in public housing projects [14].

In Hong Kong, prefabrication components, also known as precast components, traditionally refer to various small two-dimensional building components (e.g. facades, semi-precast slabs, staircases, partition walls, beams) manufactured off-stie which still need to be connected with each other and/or to the main structure using cast-in-situ concrete [15]. During the past two decades, a new form of three-dimensional precast component known as volumetric unit (e.g. kitchens, bathrooms) has emerged [16]. The pipes and ducts of such volumetric precast components are casted in factories [17], which can in turn enhance construction efficiency.

Notably, in addition to the common understanding that prefabrication is capable of enhancing the quality, safety and efficiency of construction [18], prefabrication has a multitude of other advantages over conventional cast in-situ construction. For example, the use of precast components with painting and tiling finishes, or even pre-installed utilities in the case of volumetric units minimizes the number of onsite wet trades, one of the major sources of construction waste [19]. Prefabrication also eliminates off cuts of construction materials such as bricks, tiles, pipes and steel bars which are unavoidable in the case of conventional construction [20]. Despite the benefits reaped by precast construction, adoption of prefabrication is constrained by a number of barriers. For instance, it is not suited for sites without sufficient onsite storage areas and site access [21]. Another major constraint is that prefabrication requires significantly higher logistics costs than conventional projects for two reasons. Firstly, precast components are prohibitively heavy which can only be erected using heavy-duty tower cranes [19]. Secondly, precast components require additional protection and fixation, as well as a careful loading process to minimize the possibility of damage during transportation [22].

2.2 Past Literature on Evolution of Prefabrication and Waste Management Performance of Prefabrication Projects

Upon a review of literature, there is a lack of recent studies on the evolution of prefabrication construction. Jaillon and Poon [16] had explored the trend of prefabrication adoption in residential projects of Hong Kong by analyzing five prefabrication projects completed during different periods through face-to-face interviews with the relevant stakeholders of each project. By way of field surveys with major prefabrication companies as well as interviews with both industry players and academics, Linner and Bock [23] investigated the evolution of Japan's prefabrication industry, particularly the changes in role played by the prefabrication industries over the years. Contrarily, there are more recent studies examining waste management performance of prefabrication projects, and all of them suggested that precast construction is conducive to reducing construction waste [7, 24–27]. By adopting a mixed-method approach comprising questionnaire survey, interviews and direct observations, Bari et al. [28] assessed the impact of prefabrication on time, cost, quality, labor usage and waste reduction, and found that prefabrication can help minimize waste generation.

One commonality among past studies on evolution of prefabrication and effect of prefabrication on waste management performance is that most of them had employed ethnographic approaches such as observations, interviews and questionnaires. However, it is worth to be noticed that the accuracy of data gathered by ethnographic means such as interviews might be jeopardized by the interviewees' memory lapses [29]. This is particularly the case where the interviews were conducted a couple of years after completion of the sample projects. The lack of recent studies on the evolution of prefabrication adoption as well as the effect of prefabrication on waste minimization specifically targeting at Hong Kong's residential developments calls for the need to bridge such research gap via using more objective secondary data.

3 Research Methods

This study is a comparative study encompassing two main steps. The first step is data collection, which comprises three stages: (1) sample identification; (2) collecting data on prefabrication adoption in the sample projects; and (3) collecting construction waste generation data of the sample projects. The second step involves analyzing the data collected to explore the following: (1) trend of prefabrication adoption in public and private residential projects; (2) difference in waste management performance between prefabrication and conventional residential projects; and (3) which category(ies) of precast components are the most conducive to waste minimization. In taking the second step, one supplementary interview with an architect had been conducted to understand certain phenomena identified from comparing the trend of prefabrication adoption between the public and private sectors. Figure 1 provides a summary of the research methods.

3.1 Data Collection

3.1.1 Sample Identification

We have identified 90 sample projects completed during the period from 2009 to 2019 from a database provided by the Hong Kong Environmental Protection Department (HKEPD). The sample projects must meet the following two criteria:

(1) Being "high-rise residential developments" (i.e. excluding small houses); and
(2) Being "relatively sizeable", with total GFA exceeding 3,500 m^2.

Among the 90 sample projects being selected for this study, 80 of them were prefabrication projects and 10 of them were conventional ones. The numbers of prefabrication projects initiated by the public and private sectors were 30 and 50 respectively. All conventional projects were private developments.

3.1.2 Collection of Data on Prefabrication Adoption and Construction Waste Generation

We gathered data on the specific types of precast components being employed in each sample project by browsing its building and structural plans, both of which were obtainable from the two online systems of HeBROS and BRAVO run by the Hong Kong

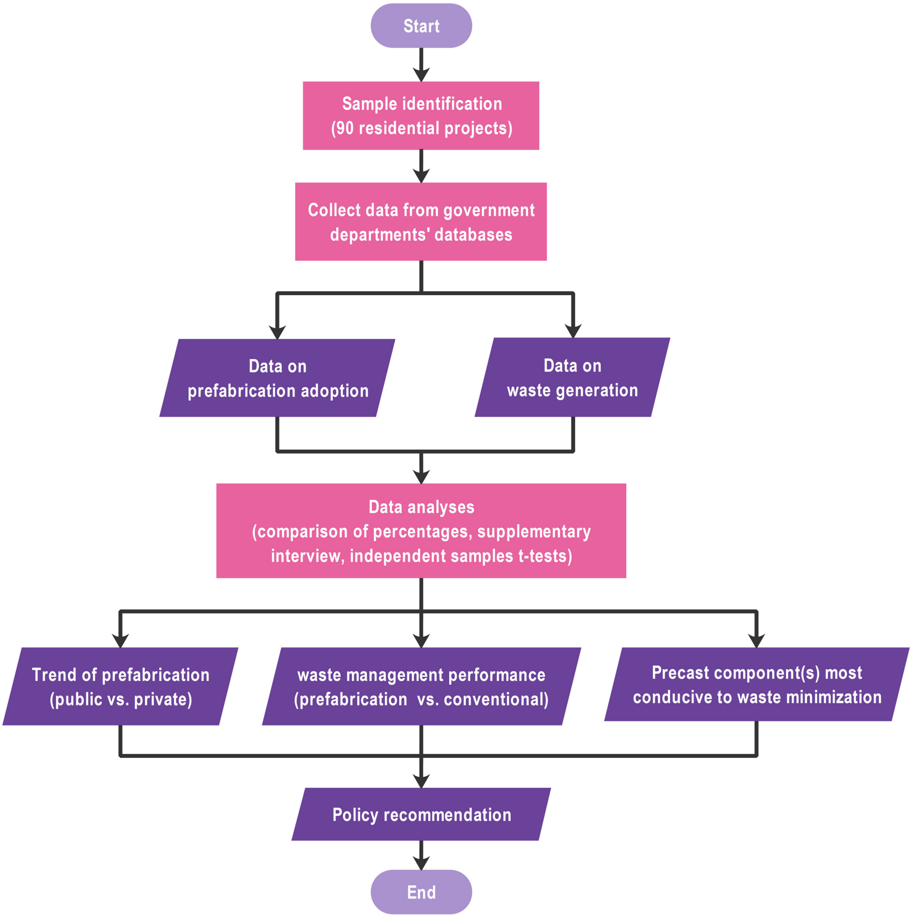

Fig. 1. Summary of research methods

Housing Authority (HKHA) and Buildings Department (HKBD) respectively. Thereafter, we have categorized the precast components being adopted in the sample projects into seven major categories, and some categories comprised several different types of specific precast components. The frequencies of usage of different types of specific precast components were presented in Table 1.

Overall, it appears that residential projects completed during 2009 to 2019 had incorporated an array of precast components, with precast façades, staircases, beams, bay windows, semi-precast slabs, partition walls, and non-structural external walls being more common. Nevertheless, when taking a closer look at Table 1, it is obvious that the range of precast components adopted by private residential projects was much narrower than that of public projects. None of the private projects had included any precast volumetric components. It is also worth to mention that precast facades, bay windows and non-structural prefabricated external walls were amongst the three more commonly adopted precast components in private projects.

Table 1. Prefabrication adoption in sample residential developments completed from 2009 to 2019

Category of precast component		Specific type of precast component	Number of residential projects		
	Name		Public	Private	Total
1	Façade	Precast façade	30	47	77
2	Staircase	Precast staircase	29	2	31
3	Beam	Precast beam	29	0	29
4	Window	Precast bay window	4	23	27
		Precast window frame	0	9	9
5	Slab	Semi-precast slab	21	3	24
		Full precast slab	14	0	14
		Precast plank	17	1	18
		Semi-precast plank	1	0	1
6	Wall	Precast partition wall	23	13	36
		Precast structural wall	0	1	1
		Semi-precast structural wall	2	0	2
		Non-structural prefabricated external wall	19	30	49
		Precast hanger wall	3	0	3
		Precast parapet wall	6	1	7
		Precast lost form	1	14	15
7	Volumetric	Precast bathroom	8	0	8
		Precast kitchen	2	0	2
		Precast water tank	19	0	19
		Semi-precast water tank	3	0	3
		Precast refuse chute	15	0	15

Being the most frequently used precast component in both public and private projects, precast facades, which constitute the outermost layer of a building, do not restrict the possibility of future spatial arrangement changes to meet market demands [21, 30]. Such comparative advantage over most other internal precast components renders precast facades particularly appealing to private developers. Meanwhile, the high popularity of non-structural prefabricated external walls and precast bay windows can be explained by the prevailing public policies of Hong Kong. To promote the construction of green buildings, the government had promulgated Joint Practice Note No.2 [31] in 2002 (revised in 2019) under which non-structural prefabricated external wall components meeting the relevant criteria and conditions can be exempted from GFA calculation. In turn, the inclusion of non-structural prefabricated external walls in residential developments yields the benefits of maximizing their actual permissible GFAs as well as the net profits of developers. Similarly, bay windows may also be exempted from GFA calculation pursuant to Practice Note Issue No. 4/2014 [32], which accounts for the relatively high usage of precast bay windows in private projects.

With the aid of HKEPD's Waste Disposal database, we obtained data on the total amount of construction waste generated by each sample project. Thereafter, the WGR of each sample project was obtained by dividing its total waste generation (in tons) by its GFA (in m^2). The GFAs of both the public and private sample projects were obtained from the building plans available on HeBROS and BRAVO. A lower WGR implies better waste management performance [33].

3.2 Comparative Study by Way of Statistical Analyses

To garner an overview of the trends of prefabrication adoption in the public and private sectors as well as to make a comparison between the two sectors, the sample projects from each sector were being further divided into three subgroups based on their year of completion. Under such categorization, public residential projects completed during the period from 2009 to 2013 constitute one group, those completed from 2014 to 2016 constitute the second group, and those completed from 2017 to 2019 constitute the third group. The same arrangement applies to the private residential projects.

Next, to explore the waste management performance of different types of projects, we employed independent samples t-tests using IBM SPSS (version 27) to make the following comparisons in terms of average WGRs:

(1) between prefabrication and conventional projects; and
(2) between private prefabrication and private conventional projects.

Thereafter, we performed independent samples t-test to investigate whether usage of different levels of precast window, slab, wall and volumetric components yield significantly different effect on waste minimization.

4 Data Analysis, Results and Findings

4.1 Trend of Prefabrication Adoption in Public and Private Residential Projects

Table 2 presents the percentages of public and private residential projects using different types of precast components during the periods from 2009 to 2013, 2014 to 2016, and 2017 to 2019 respectively.

Table 2. Proportions of public and private residential developments incorporating different types of precast components from 2009 to 2019

Category of precast component		Specific type of precast component	Percentage (%) of residential projects					
			Public			Private		
			2009–2013	2014–2016	2017–2019	2009–2013	2014–2016	2017–2019
1	Façade	Precast façade	100	100	100	88.89	82.35	68.75
2	Staircase	Precast staircase	87.5	100	100	11.11	2.94	0
3	Beam	Precast beam	100	91.67	100	0	0	0
4	Window	Precast bay window	12.5	16.67	10	55.56	44.12	12.5
		Precast window frame	0	0	0	22.22	17.65	6.25
5	Slab	Semi-precast slab	37.5	75	90	0	5.88	6.25
		Full precast slab	12.5	58.33	60	0	0	0
		Precast plank	12.5	66.67	80	11.11	0	0
		Semi-precast plank	0	0	10	0	0	0
6	Wall	Precast partition wall	75	75	80	33.33	23.53	12.5
		Precast structural wall	0	0	0	0	2.94	0
		Semi-precast structural wall	12.5	0	10	0	0	0
		Non-structural prefabricated external wall	75	41.67	80	66.67	50	37.5
		Precast hanger wall	0	25	0	0	0	0
		Precast parapet wall	12.5	8.33	40	0	2.94	0
		Precast lost form	0	8.33	0	33.33	29.41	0
7	Volumetric	Precast bathroom	12.5	25	40	0	0	0
		Precast kitchen	12.5	0	10	0	0	0
		Precast water tank	2.5	58.33	100	0	0	0

(*continued*)

Table 2. (*continued*)

Category of precast component		Specific type of precast component	Percentage (%) of residential projects					
			Public			Private		
			2009–2013	2014–2016	2017–2019	2009–2013	2014–2016	2017–2019
		Semi-precast water tank	0	8.33	20	0	0	0
		Precast refuse chute	50	66.67	30	0	0	0

On the whole, while prefabrication had become more prevalent in the public sector, it had become less frequently adopted by private projects. Specifically, five key findings were observed. Firstly, precast façade, staircase and beam components remained popular in the public sector throughout all three periods. However, during the same periods, none of the private projects had used precast beam and the proportion of private projects using precast staircases had dropped from slightly over 10% to 0%. Additionally, the proportion of private projects using precast façade had drastically dropped by over 20%. Secondly, contrary to the public sector where precast window components had never been widely used, more than half of the private projects completed during 2009 to 2013 had incorporated precast bay windows, although such relatively high proportion had significantly dropped to slightly more than 10% during the period from 2017 to 2019. Thirdly, despite that there had been a continuous upward trend of deploying precast slab components in public projects from 2009 to 2019, precast slab components had never been prevalent among private projects from the outset. Fourthly, while precast wall components had been increasingly popular in public projects, they have been getting less prevalent among private projects. For example, as shown in Table 2, the percentage difference between public and private projects completed from 2009 to 2013 in terms of adoption of non-structural prefabricated external wall was less than 10%. Yet, such percentage difference had expanded to over 40% during 2017 to 2019. Fifthly, although precast volumetric components had become increasingly common in public projects, they had never been used by the private sector throughout the three periods.

Obviously, the government's widespread use of different categories of precast components can be attributed to the long-standing issue of housing shortage and unreasonably high property prices in the private sector of Hong Kong, a city with population density being nearly 7,000 people/km^2 [34]. To increase the supply of public housing within a short period of time, the most direct means is to use precast components, which had been widely recognized as being capable of maximizing construction efficiency. Meanwhile, as developers are entitled to GFA concessions by including non-structural prefabricated external walls and precast bay windows, it is such an interesting phenomenon that they have become less inclined to use these two precast elements. To further explore such phenomenon, we have interviewed an architect with over thirty years of experience in collaborating with developers.

According to the interviewee, following the enactment of the Residential Properties (First-hand Sales) Ordinance (Cap. 621) of the laws of Hong Kong, bay windows, which had long been the root cause of saleable floor area inflation, can no longer be included as part of the saleable floor area. This accounts for their unpopularity since then. Furthermore, the reduction of the maximum thickness of non-structural prefabricated external walls eligible for GFA exemption from 300 mm to 150 mm since 2011 [35] have contributed to its lower adoption rate. As explained by the interviewee, developers could initially maximize the actual floor area and thus monetary returns of developments by constructing flats with prohibitively thick walls (with thickness of 300 mm). However, the tightening of such GFA exemption requirement had fostered developers to change their business strategies. Together with home buyers' preference for flats with high accessibility to natural lighting, developers have eventually replaced non-structural prefabricated external walls with curtain walls. The use of curtain walls, which are not as bulky as non-structural prefabricated external walls, also provides logistics convenience to developers. Thus, the declining trend of using the two precast components in private projects is a combined effect of public policy and the profit-maximizing mentality of developers.

4.2 Effect of Prefabrication on Waste Management Performance in Residential Projects

4.2.1 Comparison Between Prefabrication and Conventional Residential Projects

Table 3 provides a summary of the average WGRs and results of other descriptive statistics of the sample prefabrication and conventional residential projects. Overall, the average WGRs yielded by prefabrication and conventional residential projects were 0.79 ton/m^2 and 0.93 ton/m^2 respectively. With a 15.05% difference in average WGR, prefabrication adoption in residential projects can reduce waste generation. Nevertheless, it is worth to be noticed that such 15.05% waste reduction rate is not statistically significant ($p = 0.65 > 0.1$), indicating that other confounding variables, including but not limited to site conditions, amount of contract sum allocated to waste management and time constraints, may also impact on waste management performance.

4.2.2 Comparison Between Private Prefabrication and Private Conventional Residential Projects

As shown in Table 3, since none of the public residential projects are conventional projects, we only compare the average WGRs between private residential projects with and without incorporating prefabricated components. The average WGRs of private prefabrication projects and private conventional projects are 0.78 ton/m^2 and 0.93 ton/m^2 respectively, implying that prefabrication projects in the private sector can reduce waste generation by 16.13%. Though such difference in average WGR is not statistically significant ($p = 0.67 > 0.1$), the results do suggest that private residential projects could perform better in waste reduction if prefabrication is being adopted.

Table 3. Comparisons of waste management performance between prefabrication and conventional residential projects

Group by	Project type	Prefab.?	No. of projects	Average WGR (tons/m^2)			
				Mean	Stdev	Δ (%)	Significance#
Overall		Yes	80	0.79	0.87	-15.05	0.65
		No	10	0.93	0.84		
Client	Public	Yes	30	0.81	0.63	–	–
		No	0	–	–		
	Private	Yes	50	0.78	0.99	-16.13	0.67
		No	10	0.93	0.84		

The *p* values of independent samples *t*-tests (Two-tailed)

4.3 Effects of Different Levels of Prefabrication Adoption on Waste Minimization

According to Lu et al. [27], even two projects have employed the same number of a particular category of precast components, their actual level of prefabrication adoption may be significantly different. This is particularly the case where the two projects have used different types of precast components under the same category. For instance, both Projects X and Y have incorporated two types of precast wall components: Project X has used precast partition wall and non-structural prefabricated external wall whereas Project Y has employed precast hanger wall and precast parapet wall. It is worth to be noticed that the volume of a hanger wall (see Fig. 2) and its frequency of usage in a typical building block is much smaller than those of both precast partition wall and non-structural prefabricated external wall. Additionally, precast parapet wall normally refers to a wall with height not exceeding 1.2 m located on the building roof only [36, 37] (see Fig. 2). Thus, the volumes of precast parapet walls being incorporated in a

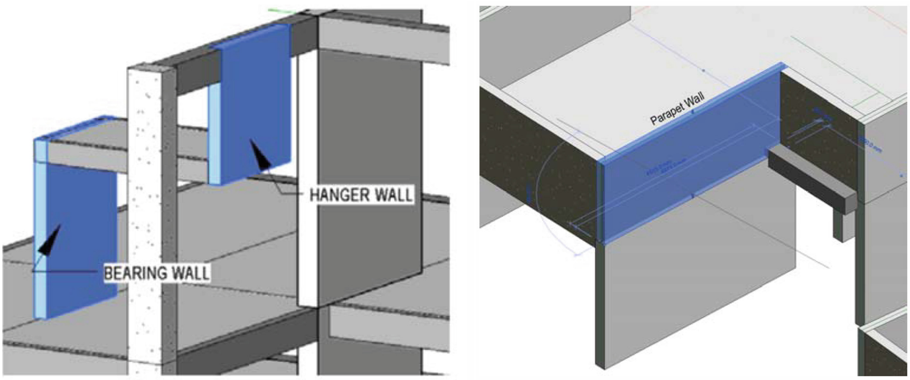

Fig. 2. Precast hanger wall (left) and precast parapet wall (right) in a typical high-rise housing block of Hong Kong (Source: [38])

building is much smaller than those of partition walls and non-structural prefabricated external walls, which are being used to construct each storey of a building. It follows that the actual number and volume of precast wall components used by Project X should largely exceed those of Project Y. With different volumes of precast components being employed, it is likely that the effects on waste minimization are also different.

In this research, we have estimated the respective levels of usage of "precast window", "precast slab", "precast wall", and "precast volumetric" components with reference to their characteristics and intensity of usage in a typical housing block. Subsequently, independent samples t-test was conducted to compare the effects on waste minimization amongst projects with high, low and no usage of each category of precast components. The results are summarized in Table 4.

Table 4. Average WGRs among residential projects with different levels of usage of precast window, slab, wall and volumetric components

Category of precast component	Estimated level of usage	Average WGR (tons/m^2)	Stdev	Significance# of comparing the average WGRs of three levels	
Window	High	0.60	0.72	High vs Low usage:	0.68
	Low	0.43	0.19	Low vs No usage:	0.34
	No	0.95	0.94	High vs No usage:	**0.05**
Slab	High	0.90	0.74	High vs Low usage:	0.19
	Low	0.49	0.44	Low vs No usage:	0.33
	No	0.90	1.06	High vs No usage:	1.00
Wall	High	0.58	0.39	High vs Low usage:	**0.05**
	Low	0.97	1.07	Low vs No usage:	0.72
	No	0.87	0.94	High vs No usage:	0.16
Volumetric	High	0.96	0.79	High vs Low usage:	0.55
	Low	0.78	0.61	Low vs No usage:	0.96
	No	0.79	0.93	High vs No usage:	0.62

The *p* values of independent samples *t*-tests (Two-tailed).

Residential projects estimated to have higher usage of precast window components generate significantly lower average WGR than their counterparts without using such component, with a 0.35 ton/m^2 difference in WGR ($p \leq 0.1$). This suggests that the inclusion of more precast window components in residential projects contributes to waste reduction. Residential projects estimated to have higher levels of usage of precast wall components had significantly lower average WGR compared with those residential projects estimated to have lower levels of usage, with a 0.39 ton/m^2 difference in WGR ($p \leq 0.1$). Together with the fact that projects with lower estimated levels of usage of precast wall components had even yielded a higher average WGR than projects without any precast wall components, this suggests that incorporation of precast wall components alone is insufficient to reduce waste. Rather, a high level of precast wall components should be used to achieve waste minimization.

Additionally, the significantly equal average WGR of 0.9 ton/m^2 ($p = 1.0$) yielded by projects with higher and no usage of precast slab components indicates that inclusion of large amounts of precast slab components in residential developments has no effect on waste reduction at all. Residential projects estimated to have lower usage and complete exclusion of volumetric precast components had significantly equal average WGR, with a 0.01 ton/m^2 difference in average WGR ($p > 0.9$). It follows that deploying small amounts of volumetric precast components has nearly zero effect on waste reduction in residential projects.

5 Discussion

Admittedly, during the period from 2009 to 2019, prefabrication adoption in the public and private sectors had gone in two opposite directions. While prefabrication remained as the mainstream in public residential projects with an increasingly wide variety of precast components employed, private residential projects had become less inclined to use precast components. Particularly, the refinement of legal requirements governing the calculation of saleable floor areas and eligibility to apply for GFA exemptions had considerably reduced developers' possible monetary gains from using precast bay windows and non-structural prefabricated external walls. This had in turn incentivized developers to open up substitutes for such components. It is against such backdrop that developers shifted to fix curtain walls in the parts of buildings originally designated for bay windows or non-structural prefabricated external walls. Furthermore, this study found that prefabrication can yield an overall 15.05% waste reduction in residential projects, and a 16.13% waste reduction in private residential projects. This goes in line with the findings of Tam and Hao [7], Jaillon et al. [24], Lu et al. [27] and Bari et al. [28], which discovered that prefabrication could contribute to waste reduction.

To further explore the effect of different levels of prefabrication adoption on waste reduction, we have compared the average WGR between projects with different estimated levels of usage of precast window, slab, wall and volumetric components using the independent samples t-test. The results indicate that adopting higher levels of precast window and wall components would be conducive to reducing waste in residential projects. By specifically exploring residential projects, this study supplements the findings of Lu et al. [27], a research based on a sample comprising both residential and commercial projects which suggests that usage of greater levels of precast window and wall components could minimize waste generation. Despite that developers have become less inclined to use non-structural prefabricated external walls due to policy changes and aesthetic concerns, the government can consider promoting the use of precast partition walls, another major type of precast wall component not affecting a flat unit's accessibility to natural lighting. The deployment of precast window frame can also be encouraged in the long run. The poor waste management performance of precast slab and volumetric components provides a probable explanation for their unpopularity in private residential developments – developers are rational decision-makers who always seek to achieve construction efficiency [39].

6 Conclusion

On the whole, adoption of precast construction does contribute to waste minimization in residential projects. Nonetheless, prefabrication has become less frequently adopted in private residential developments during the past decade following policy changes. Furthermore, when looking into individual categories of precast components, only precast window and wall components are conducive to waste reduction if greater levels are being incorporated. By using bigger data on 90 residential developments completed from 2009 to 2019 obtained from objective and credible databases compiled by the government, this study contributes to the understanding of the specific type of precast components with greater contribution to waste reduction in residential projects. It also uncovers the reasons behind the unpopularity of certain precast components in private residential developments. The findings of this research can serve as useful references for the government's future formulation of policies to incentivize the application of such green building technology. As in many studies, this research does have limitation. In this study, although we managed to obtain data on the types and subcategories of different precast components being employed in the sample projects, it is worth to note that each type or subcategory of precast component is probably made up of different specific materials. Thus, future studies exploring the impact of prefabrication on waste reduction via calculating the waste generation rate of different kinds of materials linking to particular types of precast building components are highly desired.

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