

IDENTIFYING WIDER ECONOMIC BENEFITS OF PREFABRICATED HOUSES IN AUSTRALIA

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Abstract: Prefabricated houses have been at the forefront for the delivery of buildings with less onsite construction time and safer for the workers. Significant savings in terms of cost and reducing waste are some of the primary direct benefits. In addition, other direct positive impacts such as higher quality can be easily achieved due to improvements in terms of processes offsite. However, indirect benefits of prefabricated houses are not still well defined and quantified. The consideration of wider economic benefits (WEBs) would provide the opportunity to quantify the value which is useful for decision-making. Urban renewal and growth, commercial activity influx, and employment opportunities are the examples of WEBs due to the prefabricated houses industry. WEB concept has been applied in the area such as transport and infrastructure during the decision-making. Nevertheless, there is no evidence that this concept has been applied in the prefabricated houses through a literature review and communicating with the industry in Australia. The WEBs relevant to prefabricated houses are identified. The potential methods for quantifying these benefits are discussed.

Keywords: Wider economic benefits; prefabricated houses; quantification;

1. Introduction

Prefabricated houses are at the forefront for the delivery of more efficient and higher quality houses worldwide. Significant savings in terms of time and cost, reduced waste and higher quality and better environmental performance can be easily achieved due to offsite construction [1-2]. Process stability and control can lower prices due to scale of production. The choice of materials available and consideration of passive and active heating and cooling strategies contribute to better environmental performance utilisation of [3]. The prefabrication promotes the creation of a more sustainable urban environment by reducing the onsite work and minimising neighbouring community disturbances, improving waste management during the construction and simplifing reuse and recycling at the end of the lifecycle of the buildings Additionally, [4]. the consideration of mass customisation over mass production allows companies to reach a higher level of clients' satisfaction with focus on individual customers' wants and needs [5-6].

Generally, prefabricated houses have been delivered mainly in developed countries such as Sweden, Japan, Germany, the USA and the UK. Despite Sweden's construction industry having significant experience in prefabricated houses over the past years, Japan and Germany can be considered the leaders in delivering prefabricated houses [7]. However, the delivery of prefabricated houses in Japan and Germany still represents a small percentage of the total demand of houses in both countries ranging between 9% and 16% of new buildings. The strategy used by Japanese prefabricated industries is to deliver "services" rather than "products", incorporating new technologies automation and with maintenance contracts to middle to highend market [8]. A case study from Germany showed the idea of creating high-quality product at a more than 30% reduced cost enables companies to sell their products due to efficient onsite construction in the USA and UK [9].

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1.1 Prefabricated houses in Australia

Unlike the USA and UK context, the Australian construction sector is facing challenges to deliver more efficient houses. In Australia, offsite construction remains with a minor percentage of the housing industry [7]. According to the Manufacturing Excellence Taskforce of Australia (META), in 2014, only 3% of new houses delivered in Australia were prefabricated (Crough 2015). The first attempts for the delivery of prefabricated houses in Australia was documented by Greig [10]. In that report, the interrelationship between broader societal aspects of industrialised system and its technological changes during the post-war housing crisis was discussed.

One of the main challenges Australia faces is the lack of qualified professionals and offsite manufacturing knowledge [11-12]. However, the country has been investing on research and development over the past years to developed offsite construction systems. For instance, a research from Australia showed material consumption for steel-structured prefabricated frame can be reduced up to 78% when compared to conventional concrete construction with significant potential for reuse [13]. In another study, optimisation in terms of thermal performance for retrofitting was documented and the results showed favourable contributions due to prefabrication [14].

Although vast number of studies available, Steinhard and Manley [7] emphasises there is lack of practical considerations of affordability and project costs as it should be considered within a supportive network of stakeholders and institutions. Moreover, Neville et al [15] recognised issues other than cost and time such as macroeconomic microeconomic, social and and environmental benefits are to be considered. Therefore, Wider Economic Benefits (WEBs) associated with the delivery of prefabricated houses need to be identified and quantified to reduce the risks associated with the delivery prefabricated of houses in



Australia. This study aims to identify and categorise the potential WEBs of prefabricated houses through a literature review and communicating with the industry in Australia.

2. Wider Eeconomc Benefits

According to Lai [16], there is no agreed definition on what constitutes the term Wider Economic Benefits (WEBs) as it embodies a multitude of concepts. In a broad sense, WEBs can be described as indirect benefits to the society which may be transparent not quantified. and The consideration of WEBs to the decision making process captures benefits which are usually not considered as a direct user benefits in conventional risk appraisal [16-17].

WEBs have been mainly included in large scale projects, particularly in the area of transport [17-19]. In such studies, socioeconomic evaluations assess the changes in the level of welfare among citizens for specific areas after the completion of the project [20]. The theory proposes five key WEBs for the transport projects: related business time and reliability savings, agglomeration, labour supply and job reallocation, and imperfect or increased competition [19-20]. Literature may increase benefits showed WEBs compared to traditional benefit cost analysis [16]. According to Kristensen [20], previous studies on WEBs showed an average of 40% added benefits.

Connections gross between domestic product (GDP) and welfare are show in a wider perspective as it includes, for environmental, instance, health and wellbeing aspects. Some studies acknowledged considering WEBs might cause double counting if observed from both welfare and GDP points of view [20-21].

No evidence of the consideration for WEBs in the construction sector or the prefabrication industry was found in the literature. Therefore, the WEBs related to prefabricated houses needs to be identified as well as appropriate methods for



quantifying such benefits needs to be determined.



Figure 1: The interrelationship between Welfare, WEBs and GDP, adapted from Department for Transport [21]

2.1 WEB identification for Prefabricated Houses

This section identifies the benefits of prefabricated houses from different stakeholders' perspectives. Stakeholder analysis are important for policy and program development as different actions that bear differently stakeholders will result in different benefits for each of them [22]. In the case of prefabricated houses, the major stakeholders are the developer, consultant, builder, supplier, agent, investor, occupier, community and authority [23].

2.1.1 Developer

Prefabricated houses can provide many benefits from a developer's perspective. Developers acquire an unimproved or under-improved property and are responsible to carry out improvements to, then, release the full potential of the land making the highest and best use of this asset [24]. Eventually, the developer might play both roles as developer and long-term the completion of the investor after development process [24].

Advantages in terms of construction process may lead to better sales opportunities. Cost and time reduction of construction is the primary benefit of offsite construction and may secure the delivery of the house. If the building is not delivered at the time the development is ready, sales prices may not exceed the development costs and therefore result in investment losses [24]. Also, development density needs to be considered and optimised if possible to reduce the risk of losses. Lower probability of labour's injuries onsite and lower use of water should be also considered as benefits of offsite construction. In terms of product, the marketed property needs to be attractive to the potential byers assuring incentives to development. The high level of the industrialisation provides better product's quality as more layout options guarantees advantage in terms of sales due to client's requirements [25].

2.1.2 Consultant

offsite benefit Consultants will from construction since they can specialise in technologies prefabricated for houses, having advantage over their competitors [24]. Offsite construction offers better quality, with less rework in a reduced time as components, as panels and modules are repeatedly manufactured. Also, the delivery of mass customised houses may stimulate a new niche of specialisation. For instance, consultants will be able to work with catalogue development for mass customised houses and it will therefore offer more work opportunities for architects and interior designers. Increase in job opportunity and productivity may lead to greater buying power.

2.1.3 Builder

Builders are responsible for the construction of houses, including delivery of materials and labour supply. Offsite prefabrication reduces the time onsite, and therefore the builders are able to accomplish their work in a reduced time and increase their productivity. Also, the likelihoods of injuries onsite and waste are decrease since the time of construction onsite is shorter [26]. Although the reduced time of construction, builders could be able to employ more people due to high demand of work [12]. More opportunity for working means higher income for workers and higher income for employees as well as for the builders. Product variety would provide

more market opportunities due to higher product quality and diversity of house layouts [27].

2.1.4 Supplier

Suppliers are responsible for the delivery of materials to the site of conventional houses, and, for prefabricated ones, the suppliers are usually in charge of the fabrication and delivery of components, panels or modules. Offsite construction reduces their cost and time due to high demand and efficient production, increasing job opportunities in [28]. Also, automation factories and optimisation are keys for delivering more products with high quality in a substantial reduced time. Via personal communications practioners and researchers some in Australia mentioned prefabricated houses may create new opportunities for Australia to expand its manufacturing sector, and provides employment for skilled labour from the car industry. Many studies from manufacturing emphasise car the importance of long-term partnership with suppliers provides significant as it advantage over competitors through design improvement or optimisation in the production process [29].

2.1.5 Agent

Agents are responsible for marketing the property and sales once the house is ready [24]. They will get the benefit from prefabricated houses due to reduced time of construction and quicker delivery of the development packages. It will reflect directly in the investments since the investor or occupier will not need to wait a long period for purchasing their asset. Also, having different house options available will increase their capacity to sell the product according to clients' requirements. If agents sell more houses in a shorter period, they have more profit and, as a consequence, having more money to spend locally. Another indirect benefit of prefabricated houses mentioned by an industry collaborator is the advantage of a more sustainable offering product previously non-viable in the market [26].

2.1.6 Investor

Investors are the buyers of the development packages [24]. They look for economic benefits from receipt of rental income and capital gain by purchasing a house they want to sell or rent, according to their wants, needs and willingness to pay. Despite land purchase being the most significant expense investors may find, the benefit of getting a house ready in a short period is generating revenue quicker. It will reflect directly in the investments due to less holding costs, leading to a more attractive product when compared with conventional houses. The fact that investors can purchase houses in a shorter period is expected to change the sales figure to a significant growth in a macro scale.

2.1.7 Occupier

Occupiers can be owner or the tenant of the house. If they are the owner, they will choose to purchase a product that meets their requirements under a price they are willing to pay [30]. For tenants, location, facilities and price are some of the features they might prioritise when choosing a place to live in. A product which meets individual requirements with higher level of quality and under an acceptable price stands out among conventional houses due to competitiveness.

2.1.8 Community

Communities are the stakeholders which obtain more benefits from prefabricated houses. According to one of the industry collaborators, prefabricated houses may communities provide with better purchasing power as their utility bills and mortgage will reduce significantly and, thus, they will have more money to spend locally. Reduced time of work and safety onsite provides community with less noisy dust impacts. The creation and of manufactured house's industries requires people working at factories, providing new employment opportunities and stimulating the urban growth. Also, the large scale production of houses will also result in local economic growth as the benefits of other stakeholders will affect the community in a wider perspective. Ageing population



would also benefit from prefabricated houses [8].

2.1.9 Authority

Authorities are also highly benefited from the delivery of prefabricated houses [1]. Reduced time onsite means authorities are able to receive taxes guicker. The reduction of injuries onsite is also an indirect benefit for the public service as the probability of harms reduce significantly [11]. Reduced waste materials [26] and water use are also under authorities' responsibility and it is a authorities. In benefit for addition, population growth is also one of the major problems worldwide. If more houses can be built in a short period with less impact to both environment and society, then, the local economy will be stimulated by not only the construction industry but also the local buying power, leading to economic growth.

3. Benefit Transfer Methods

Johnston et al. [31] defined benefit transfer methods as "the use of research results from pre-existing primary studies at one or more sites or policy contexts to predict welfare estimates such as willingness to pay or related information for other, typically unstudied sites or policy contexts (often called policy sites)" [31, p. 20]. Benefit transfer methods is generally used in environmental policy analysis [32] when time, funding, data availability are constraints of the original research and therefore pre-existing estimates are required [31]. Benefit transfer can be described into two different types [31 & 33]. The former is related to a single unadjusted value which is whether adjusted according to the policy context attributes or experts' opinion. The latter considers in the level of policy site which uses aggregation on average of from previous studies usually values measured by a median value based on the literature or from a variety of estimates from a set of prior studies.

3.1 Unit value transfer

Environmental resources, such as willingness to pay, can be estimated

opinion according to individual's on welfare, the choices they make or hypothetical situations based on expert's opinion [31]. Marginal welfare across site can be translated into benefit transfer for individuals or population's. The least accurate and simpler form adopts a single unadjusted value, assuming the willingness to pay is equal to the defined policy site. If policy site data is unavailable, the second form adjusts the transfer estimates as per currency value, income or other factors. It can also utilise values transfer adjusts estimates based on expert's opinion. adjustments comprise However, such strong assumptions and may lead to additional transfer errors.

3.2 Benefit function transfers

As opposite to unit value transfer, the *benefit* function transfer method requires parameterised function for calculating the empirical outcome of interest and a subset of the variables for the policy site [31]. It estimates a welfare to more than one selected features of a policy site. In this case, transferred function is calibrated and adjusted from a specific study to the policy site context [31]. The simpler form is a single-site benefit function which calculates a calibrated welfare estimate for a specific policy site and includes different types of study such as choice experiments, recreation demand models, contingent valuation studies [31 & 33]. In this case, the data is gathered from a single primary study. When no policy site data variables are available, other variables are used such as original values from the same study.

For *benefit function transfer across sites*, multiple-site benefit function analysis should be considered as it takes into account the use of independent single-site transfers, resulting in a condensed and single estimate. Meta-analysis is generally used to generate a "single umbrella" of benefit function, when there are different studies and/or sites that needs to be statistically combined [33]. Meta-analysis includes the use of Meta-regression models (MRMs) and Bayesian MRMs.



Johnston et al. [33] emphasised that benefit methods transfer are still under misunderstanding as its reliability and validity have been under questions. In addition, there is no agreement as to whether unit transfer of function transfer is most appropriate method the [34]. However, benefit function transfer method is the more statistically rigorous as it involves valuation function to adjust benefit transfers estimates for differences in terms quantity, quality, individual's of or population characteristics or any other characteristics related to the site as price, quality or any similar product available [31].

Scaling over quantities, populations and geographic areas are generally applied for benefit transfer. Figure 2 shows the standard downward marginal benefit curve which is applied for both market and non-market good [31].





Figure 3 displays the relationship between marginal benefits per person and the distance from the outcome. Studies proves the individuals are generally willing to pay more for environmental improvements which are close to their homes [35-36].

4. Discussion

As a significant amount of studies for quantifying WEBs has been carried out in the transport sector, this section describes potential application of benefit transfer method for quantifying WEBs in the prefabricated construction industry. Value of time savings and productivity, employment, competition and



Figure 3: Marginal benefits per person and distance from outcome [31]

agglomeration effects for prefabricated houses are discussed.

For prefabricated houses industry, time saving is viewed as the ability of delivering houses in a reduced time due to high productivity, which might positively affect the sales, resulting on WEBs of competitive markets. Time saving benefits most of the stakeholders. Not only owners may benefit from time saving due to early availability of their property, but also investors, builders and agents who are able to acquire their investments or revenues earlier and authorities will be able to collect taxes. This is differ from value of time savings for infrastructure projects regards the effects of relative individual's route time savings resulted roads quality, which reflects in productivity [20]. However, efficient processes will provide better productivity in factories for prefabricated houses as productivity will affect value of time savings [37]. Moreover, the commuting distance from work is a factor that influences in productivity and might reflect on employment.

Employment effects are consequences of value of time savings and productivity and may have various impacts in different regions. Labour deficiency, level of qualification of available workforce, distance from worker's house to the workplace are factors which should be considered when quantifying WEBs. In addition, elasticity of employment may vary according to the place in both short and



Imperfect competition is not considered in conventional socioeconomic analysis. However, firms are generally in imperfect competition as they produce differentiated goods [38]. As productivity tends to increase reduction in delivery time, it is postulated that individual's benefits are under such circumstances. greater Therefore, imperfect competition effects result from many different elements such as time, productivity, local GDP and others.

According to the Department for Transport [21], companies can be more productive and benefited from a agglomeration effects. When companies are located in closer geological regions (e.g. near economic centre or large employment areas), they find better access to larger pool of products, input and labour markets [20, 28 & 39]. WEBs of agglomeration effects can be identified through the elasticity of total productivity with respect to the density of employment in one specific area, change in the effective density of employment and the local GDP [21]. Prefabrication factories of modular houses may stimulate activities and contribute to agglomerations, productivity enhancing local and stimulating growth [28]. Since no documentations were found in previous studies, WEBs agglomeration effects need to be carefully quantified as agglomeration changes elasticity amongst different industries [20].

Labour supply benefits is usually not traditional included in socioeconomic analysis [20]. However, labour skills for prefabricated houses in Australia is an important factor that needs to be considered due to lack of qualified workforce and other factors [12]. From an individual's point of view, any welfare will be gained without job, however, labour supply will reflect in the revenue due to tax increases for companies. Therefore, labour market effects need to consider productivity and time savings as well as skilled labour force

for the benefit of both individuals and companies.

The unit value transfer method and benefit function transfer method may be applied in different situations according to the level of the analysis and data available and, therefore, limitations of its utilisation need to be identified. Table 1 presents the data available for quantifying each of the identified WEBs of prefabricated houses and the data required by the methods. For instance, value of time savings, productivity and employment requires accuracy as such aspects relies on a subset of the variables for the policy site.

Competition effects and agglomeration effects are not necessarily determined by a specific geological region. At the same time, it could be reduced to a specific location. Similarly, labour market effects is subject to the type of approach. WEBs of labour market effects can be quantified from two different perspectives: firms' point of view or individual's point of view, ranging from a generalised to a more statistically rigorous approach.

Table 1: Available and required data for quantifying WEBs according to benefit transfer methods

WEB	Ur tra me	Unit transfer method		Function transfer method		
Required data	а	b	С	d	e	f
Value of time	e 🗌					
savings						
Productivity						
Employment						
Competition effects						
Agglomeration						
effects						-
Labour marke	et 🖂					\mathbf{v}
effects						T

Y = yes, N = no, - = not applicable.

- a. Individual's opinion on welfare
- b. The choices individuals make
- c. Hypothetical situations based on expert's opinion
- d. Subset of the variables for the policy site



- e. Welfare to more than one selected features of a policy site
- f. More than one policy site

5. Conclusions

Since the identification and quantification of wider economic benefits (WEBs) are new for prefabricated aspects the houses manufacturing industry, this study is an important preliminary step for the delivery of more sustainable and efficient houses in a perspective for the wider Australian context. Studies and archival reports on WEBs are originally from infrastructure projects, mainly related to the transport area and its application was confined to this area at the moment. However, the case studies documented in the literature shown potential applicability to different areas, including the prefabricated construction industry, with relevant outputs and high level of credibility. Therefore, in this study WEBs of prefabricated houses in Australia have been identified and categorise, and the available potential methods for quantifying these benefits have been discussed.

а Through literature review and communicating with industry collaborators, this paper presented various stakeholders' point of views. The potential WEBs which are usually not recognised in conventional evaluation economic of building construction have been discussed to provide a broad understanding. Value of time productivity, employment, savings, competition effects, agglomeration effects and labour market effects are identified as the main WEBs of prefabricated houses. The unit transfer method and function transfer method are the potential quantification methods.

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