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Feasibility of Application of Modern Methods of Construction in Iran

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Abstract

Various plans and policies have been adopted by the Iranian Government to address the housing shortages in Iran. Some of these policies have been successful and some have failed dramatically deteriorating the housing conditions. Technology transfer from other countries, such as the UK, may facilitate industrialisation which has been recognised as an effective way to address housing deficiencies in Iran. The Iranian and UK construction industries, however, differ in various respects which may increase the risk of failure if transferred technologies are not adapted to Iranian needs and conditions. This paper compares the current conditions of the Iranian and UK construction industries to identify the risks and opportunities if Modern Methods of Construction (MMC) were to be transferred from the UK to Iran. Several issues such as demand and supply, regulations and standards, practicality, costs, design, sustainability, and governmental policies have been studied in detail. The results reveal that MMC could potentially improve the housing conditions in Iran by addressing major issues such as skilled labour shortages, energy and materials wastes, building quality and speed of construction. The major risks are also identified as volatile economy and housing market, transportation and industry capacity. The chance of successful adoption is considerably higher for those MMC that are suitable for small projects, do not require highly skilled labour and heavy machinery, and are compatible with prevailing methods of construction in Iran.

Keywords: *Modern Methods of Construction; MMC; construction technology; housing; technology transfer; Iran; UK.*

1. Introduction

During the last few decades, the Iranian Government has adopted various plans and strategies to improve the housing conditions in Iran. Some of these plans have been successful and some have failed dramatically deteriorating the housing conditions. It is estimated that over one million residential units are currently required to be constructed annually (BHRC 2009) to answer the current demand. The current housing output should almost be doubled (Hashemi and Hadjri 2014) in order to answer the demand during the next 15 years. This is by far beyond the current capacity of the Iranian housing industry. For this and many other reasons, Industrialisation and Modern Methods of Construction (MMC) have been suggested as effective ways to increase the housing output in Iran (Hashemi 2015).

MMC can be classified under five main building methods of: 1) volumetric systems; 2) panel systems; 3) hybrid systems; 4) sub-assemblies and components; and 5) site-based methods (Ross et al. 2006). MMC have several claimed advantages over traditional methods of construction such as higher speed of construction; improved quality and health and safety; addressing skilled labour shortages; minimising material waste; enhancing value for money invested; and cost predictability (Buildoffsite 2013; Myers 2013; Miles and Whitehouse 2013).

Such potential advantages of MMC over traditional methods of construction have encouraged the Iranian and UK governments to promote MMC with the intention to improve the housing outputs as well as the quality and energy efficiency requirements. Yet, despite governmental supports and incentives, the share of industrialised methods in Iran has remained considerably lower than expected. In 2008, for instance, the share of industrialised construction methods was less than 3% of (Fatemi Aghda 2008). Several reasons such as small scale of projects, costs and limited knowledge of stakeholders about advantages and risks of such methods have been suggested for the limited application of industrialised construction methods and the failure of previous attempts in Iran (Hashemi 2014; Hashemi 2015).

When considering the transferability of MMC to Iran, some additional criteria are involved; some are desirable, some absolute; some controllable, some uncontrollable; some measurable and some immeasurable. Some areas are of particular importance in the Iranian context as follows:

a) Demand and supply
b) Practicality
c) Costs
d) Energy efficiency and waste reductions
e) Regulations and standards

In the following sections, these criteria are examined and key differences between the Iranian and UK conditions, potentials, and limitations are discussed in detail. The aim is to evaluate the opportunities and difficulties facing MMC if transferred to Iran.

Research Methodology

The methodology of this paper is direct comparison between the Iranian and UK construction industries. It is aimed to identify and then evaluate the risks, barriers and opportunities if MMC were to be applied in large industrial scales Iran. Relevant documents in English and Farsi languages published by individual researchers, Iranian and UK governments, and other research bodies are studied. The outcomes of the study are then discussed in detail to identify the critical factors which affect the feasibility of application of MMC in the Iranian construction industry. Some recommendations are then drawn based on the findings of the research as the way forward.

2. Detailed comparison between the Iranian and UK construction industries

This section intends to discuss the abovementioned criteria in order to identify differences between the Iranian and UK conditions and to highlight opportunities and risks facing MMC in Iran. To emphasise the interactions between the identified criteria, all factors involved in a particular topic are included even though this necessitates some repetition.

2.1 Demand and Supply

The UK construction industry accounts for 8.7% of the country's GDP (BERR 2009). The share of the construction industry in the Iranian economy is around 5% of GDP (CBI 2014) of the Iranian economy (CBI 2013a). In 2003, the private sector was responsible for around 90% of the residential buildings in the UK (Lovell 2003) which decreased to just above 78% in England during 2012-13 (DCLG 2013). Prior to the "Mehr Housing" programme which was introduced by the former Iranian government, private sector was responsible for around 95% of the residential buildings in Iran. This figure, according to the published documents by the Central Bank of Iran, decreased to around 63% in 2011/12 (CBI 2013b). The share of the private sector returned back to more than 95% in 2012/13 (SCI 2013a). The housing sector is one of the few Iranian industries where the government's share is much less than the private sector, giving developers and potential investors the freedom to follow their plans in applying MMC without much control from the government.

Iran needs around 1.5 million new houses to be constructed annually by 2025 to answer its cumulative housing demand (BHRC 2009). According to the Statistical Centre of Iran, housing production was 693,670 units in 2007 (SCI 2008), 621,492 in 2009 (SCI 2010), 701,806 in 2010 (SCI 2013a), 765,024 in 2011 (SCI 2012), and 729,933 in 2012 (SCI 2013a) and 770,410 in 2013 (SCI 2014), which means an average of around 705 thousand units per annum since 2007 (**Table 1**). The annual housing production should therefore increase by an average of 800,000 to answer the current demand. This figure rises to more than 1000,000 housing units if the shortfall of the previous years since 2007 is brought into the account. Although the Iranian government has been trying to increase the housing supply, housing demand has been increasing inexorably year by year as the current housing output is not capable of dealing with such huge demand.

Table 1: Housing output 2007-2013.

Year	2007	2008	2009	2010	2011	2012	2013
New housing units	693,670	650, 000 (Est.)	621,492	701,806	765,024	729,933	770,410
Average				704,627			

The UK situation is different in terms of the housing demand and supply. The demand is estimated to be around 233,000 housing units per annum during the next twenty years (CIH 2012); however, the recent housing recession considerably affected these figures. Housing supply in 2010 and 2011 was 103,000 (CIH 2011) and 146,000 (134,900 units according to DCLG (2012) units respectively (Pawson and Wilcox 2013).

The cost of an MMC factory including staff training is over £10 million in the UK (Lovell 2003) and, therefore, potential investors need to be assured about the long-term continuing demand for MMC products. Comparing the Iranian and the UK conditions reveals that the housing demand in Iran is over six times greater than in the UK which could be regarded as a continuing long-term demand for MMC products. The massive housing backlog in Iran is a great opportunity for MMC to be successfully adopted by the construction industry.

2.2. Practicality

Iran suffers from the shortages of skilled construction labourers, availability of heavy machinery, and inefficient infrastructure and transportation systems. Availability of raw materials is also a fundamental issue. Reinforced Concrete (RC) and Steel frame systems are the most common construction systems in Iran. According to SCI (2013a) about 82.5% of new buildings in 2012 in Iran were constructed from either steel or reinforced concrete frame systems. Steel and reinforced

concrete systems are therefore very well known to Iranian architects, engineers and builders (**Figure 1**). Thus, those MMC that are compatible with steel and concrete frame systems will have a higher chance of success in Iran.

Figure 1: Construction methods in Iran.

Industrial capacity not only deals with the availability of raw materials, labour, and machinery, but also the capacity to answer the demand. It should be noted that to increase the construction production modestly in a national scale, there should be a substantial investment in production of raw materials to create a new capacity. The investment on raw materials should be based on the future demand for them (Harvey and Ashworth 1997). A lack of industrial capacity regarding availability and production of raw materials was one of the major reasons that resulted in the failure of Winston Churchill's 1944 emergency housing plan to produce 500,000 housing units without increasing demand on conventional building resources and skilled labour (Finnimore 1989). Increasing production capacity for raw materials and improving infrastructure are therefore key to successful application of MMC in Iran.

2.3. Costs

The costs of MMC should be comparable with the prevailing methods of construction in Iran. Higher costs of MMC products are a major barrier to broader applications of MMC in both Iran and the UK. The average cost of MMC in the UK is currently 8-15% more than traditional methods (CABE 2004) and it has been estimated that such materials and products could be up to four times more expensive in Iran than in other countries (ICC 2005). Nevertheless, some examples in the UK, such as Design for Manufacture (DfM) 60K house competition in 2005, prove that MMC can produce affordable, high quality, sustainable houses (English Partnerships 2006; HCA 2010).

Transportation distances are also one of the barriers towards broader application of MMC in the UK since well-established factories are situated in the north of England while the demand is in the south (Bagenholm et al. 2001). This is also an important issue in Iran since Iran is a vast country and transportation can considerably increase the costs. Recent increases on fuel costs in both Iran and the UK make this issue more important. MMC factories should therefore be located around the areas where the current and future demands are concentrated. It is vital to avoid unnecessarily long transport of materials/products, which increase costs and CO_2 emissions of MMC.

Meanwhile, construction material and labour costs are much less in Iran than in the UK; however, inflation is much higher (average of 21.5% in 2011 (CBI 2013c) and the economy is less stable. According to Statistical Centre of Iran, the increased costs of construction materials in 2012 varied

between 22.5% and 180.5% compared to 2011 in Tehran (SCI 2013b). The majority of construction materials have seen an increase of more than 35% while many have seen a price increase of above 100% during this period which is much higher than the average inflation. These factors can considerably affect the finished prices of MMC in Iran; however, the same situation applies to other products and industries.

Other issues such as lower quality and much more material waste (explained below) as well as much higher construction dead-load, make the Iranian traditional construction methods rather more expensive than those in the UK. Therefore, while MMC are about 8-15% more expensive than the traditional methods of construction in the UK (CABE 2004), the finished prices of some MMC may be well below the costs of the conventional methods in Iran. Moreover, because of low quality of materials and poor workmanship (Figure 2), Iranian buildings have a short lifespan and are vulnerable in the event of earthquake (Hashemi 2014). The average building lifespan in Iran is about 30 years (Fatemi 2009) compared to the normally expected building lifespan of 60 years. Due to better quality controls in the factory, MMC can potentially produce buildings with longer lifespans and less maintenance, leading to personal and national savings particularly in terms of the embodied energy of buildings. In addition, the higher construction speed of MMC means enhanced value as investors' money will not be bound up in one project for a long time.

Figure 2: Low building quality in Iran.

An important issue is the nature of the Iranian construction industry with many small builders which makes it difficult to benefit from mass production and economies of scale. Statistics suggest that in 2008, 40% of all newly constructed residential buildings in Iran had three or more stories and 30% have three or more units. This figure increased to 53% in 2012/13 (SCI 2013a). Mass building appears to be much more prevalent in some parts of the country and especially around big cities (**Figure 3**). For instance, in 2012/13, 93.5% of the building permissions for residential buildings in Tehran were issued for buildings with five or more stories with around 52% which had five or more residential units (SCI 2013a). Yet, compared to the UK, a very few projects may be considered as mass building to benefit from the economies of the scale even in large cities such as Tehran. Therefore, transferred MMC to Iran should be capable of supporting small developers/projects.

Figure 3: Use of MMC is more viable in larger construction projects.

2.4. Energy efficiency and waste reductions

Sustainability and energy efficiency in buildings are relatively recent issues in Iran; however, they are becoming increasingly important. One of the main barriers toward applying energy efficiency plans are the very low prices of energy. Energy efficiency regulations became mandatory for all buildings in urban areas in 2010 (IFCO 2015). The government has also reduced the majority of fuel subsidies, which has considerably increased the prices revealing the importance of energy efficiency to the society. Yet, compared to the UK, energy costs are much lower in Iran. According to the Iranian Fuel Conservation Company (IFCO), building costs in Iran increase by less than 5% if energy efficiency requirements are applied correctly. Such extra immediate costs are returned in about three years (IFCO 2009). UK building regulations have much higher energy efficiency standards than the Iranian ones, which could make UK MMC products comparably expensive if transferred to Iran. Therefore, transferred MMC should be modified and adapted to comply with the Iranian standards and requirements to reduce the costs.

Table 2: Waste reduction potential of offsite methods of construction (Hartley and Blagden 2007).

Offsite Method/Products	Waste Reduction (Est.)
Concrete Panel Systems	20-30%
Timber Frame System	20-40%

Precast Floor Systems	30-40%
Pods (Kitchen, Bath)	40-50%
Precast Cladding	40-50%
Structural Insulated Panels	50-60%
Volumetric Systems	70-90%

Furthermore, MMC can mitigate the environmental impacts of the Iranian construction industry by reducing the energy and material wastes during construction on site. Up to 70% of consumed energy in gas and electricity, and water is wasted during the construction processes (Gharazi 2004) and around 20% of building materials are wasted on site (**Figure 4**) (Shakeri 2004). The wastes can be reduced by up to 90% in the factory (**Table 2**). Therefore, introducing some MMC, which benefit from a controlled factory environment, will considerably decrease environmental impacts of the Iranian construction industry. Moreover, as described above, increased building lifespan thanks to the higher quality, not only helps to reduce the overall costs but also reduces the CO_2 emissions and embodied energy of buildings during their lifecycles.

Figure 4: Construction material storage and waste in Iran (left) and the UK (right).

2.5. Regulations and policies

Compliance with building regulations and standards is one of the major issues that should be considered when transferring a method of construction to Iran. UK building regulations and standards are generally more detailed, precise, and comprehensive than the Iranian building regulations and standards. Therefore, in general, it could be argued that if MMC were to be transferred to Iran, they would probably comply with the Iranian regulations and standards. An important exception is the necessity for earthquake-proof design in Iran. Seismic requirements are covered by so-called Standard No. 2800 (Iranian Code of Practice for Seismic Resistant Design of Buildings). As Iran is situated on the Himalaya-Alps seismic belt, earthquake is a serious concern throughout the country. Therefore, any potential MMC must comply with earthquake regulations. This, to avoid additional costs, it may be more feasible to start with some non-structural products and methods that do not need fundamental modifications to comply with Iranian building regulations. Different cladding and internal wall systems may be suitable options to begin with.

One of the major issues in Iran is the high sensitivity of the housing industry to economic conditions and governmental policies, especially financial ones. In many cases, such policies create great shocks in the housing market followed by massive house price increases in a very short period of time. Rising prices are not necessarily a bad phenomenon if they happen in a rational way but this is not the case in Iran. The experience has shown that house prices in Iran could rise by more than 100% in a very short period as happened recently in many parts of the country. For this and several other reasons, there are frequent housing booms and busts which can greatly influence the demand for housing and MMC products consequently. Obviously, the government's responsibility is to stabilise the economy since such instabilities are discouraging for potential investors. Economic instability, however, may have some benefits for some MMC too. This situation may encourage builders to use offsite methods of construction since the contract for such methods is usually set at the beginning of the project when prices are agreed. Therefore, developers do not need to be concerned about price fluctuations while the project is in progress on site.

Restrictive (subjective) planning policies are also a major barrier towards broader applications of MMC in the UK (Lovell 2003; Bagenholm et al. 2001; NAO 2005). The absence of proper planning and design policies in Iran has caused many cities such as Tehran to suffer from critical problems such as uneven texture, heavy traffic, air and sound pollution, privacy issues and massive population density in some areas. However, fewer planning limitations decrease the associated risks of MMC and increase the chance of success in Iran.

3. Discussions

The major reason for the Iranian government to encourage industrialised modern methods of construction is to increase the efficiency and housing output. Arguably, this situation is comparable with the UK conditions after World Wars when massive and urgent demand encouraged the UK government to consider prefabricated methods of construction to overcome the housing shortages. The dull and unattractive prefabricated buildings of the 20th century are widely considered to have caused some social and environmental problems, leading to the premature demolition of many such buildings. One of the outcomes of such mistakes was negative public attitude towards prefabricated methods of construction in the UK. Indeed, a negative public attitudes towards such methods due to the poor quality of prefabricated systems is a major barrier to broader application of MMC in the UK is (Lovell 2003). Iranian people, in contrast, have a fresh attitude towards MMC and prefabricated methods of construction. According to a questionnaire survey undertaken in Tehran, around 90% of architects have a positive attitude towards such methods of construction (Hashemi 2015). This is a great opportunity for MMC to be successfully applied in Iran. It should be noted that after about a century of experiencing prefabricated methods of construction, the UK is still suffering from several social, environmental, and economic problems some of which have been the outcomes of mistakes made during the past century (Hashemi 2013). Variety in products, flexibility in application and continuous development can help to avoid repeating the UK's mistakes. New approaches, such as mass customisation, could be an appropriate strategy which should be considered by the Iranian construction industry to address flexibility issues. Japanese experience in mass customised housing (Hashemi and Hadjri 2013) is a great example which could be followed by both the Iranian and UK construction industries.

Moreover, continuous demand is the key factor for successful application of MMC. Foreign systems were not sufficiently adopted by the UK construction industry until late 1950s when housing programmes grew considerably and investors became confident about local authorities

and the government's commitment to "system building". This was when foreign and UK building systems flooded into the housing market (Finnimore 1989). The Iranian government has announced some plans to support investors in MMC; however, these plans are neither sufficient nor effective in practice. Meanwhile, not only are high tariffs for imported materials normal but their rate is volatile, giving importers little certainty about the costs. Recent sanctions/embargoes and uncertainties about the currency exchange rates also contribute to the above worries. In this respect, the government should provide special facilities for innovative methods of construction to make them more feasible in Iran. Currently, considering the abovementioned risks, it seems more rational to adapt transferred MMC by minimising the use of imported materials, with a corresponding decrease in the finished prices.

Furthermore, the UK government is encouraging and promoting MMC through different activities such as research grants, best practice strategies, and national and international exhibitions and competitions. The government is also applying MMC in social housing and other governmental projects. The Iranian government can also promote MMC by considering similar policies and strategies. The number of relevant seminars held in the UK is far greater than in Iran. There are also several professional organisations such as Building Research Establishment (BRE) and Buildoffsite that are constantly working on various construction technologies and MMC, whereas in Iran, there are no professional organisations to consider MMC in detail. It is the government's responsibility to establish professional organisations to carry out more research, seminars and courses on relevant subjects. National exhibitions and competition would also help to promote MMC in Iran.

Moreover, fundamental changes in the role of designers and manufacturers are essential in order to have a successful application of MMC (Pasquire and Connoly 2003). The main question is as to how ready designers, builders, and manufacturers are to change their traditional roles and attitudes toward new methods of construction. Considering MMC is a relatively new subject in Iran, more effort may be required to change the traditional role and behaviour of the clients, designers, engineers, manufacturers, and developers in the construction industry. Moreover, these members of the construction industry have very limited knowledge about MMC (Hashemi 2015) which may increase the associated risks of MMC.

Identifying early adopters is also a key factor in successful application of an innovation. Early adopters are the most influential group in any system since potential adopters look to them for advice and information (Rogers 1995). Likely, early adopters and stakeholders of MMC are not readily apparent in Iran. There are two key questions which should be answered:

- Who are the potential investors in MMC?
- Who would be the pioneers to adopt MMC changes and their innovative approach to design, manufacturing, and management in the construction industry?

More research needs to be undertaken among different stakeholders including architects, consultants, engineers, developers, contractors, manufacturers, society, and the government to answer these fundamental questions.

A major point which makes the Iranian and UK construction industries different is that the UK construction industry works as an "Open" or "Flexible" system, meaning that many products from different manufacturers are compatible with each other. UK companies and manufacturers cooperate with each other and refer to or recommend other companies' products that are

compatible with theirs. Many products can be easily applied in different projects without concerns about their compatibility. Manufacturers also use approved contractors who work under their license to guarantee the quality of finished products. Published literature and technical help lines also assist architects and engineers to choose the right products and materials. Many seminars are also organised by manufacturers to introduce and promote their products in the market.

The situation is rather different in Iran since manufacturing systems are usually “Closed”, and different products are generally not exchangeable/compatible. Manufacturers cooperate very rarely and, for various reasons, are not willing to publish their technical information. Moreover, a very few companies assist architects and engineers during the design processes. Therefore, designers are responsible for almost all detailed design without much assistance from the manufacturers, which considerably increases the risks of errors and costly modifications particularly when it comes to offsite methods of construction. This situation must change in order to decrease the risks associated with MMC. Considering the current conditions, three options with regards to transferring MMC to Iran appear viable:

- To transfer a “Closed” system where every single component is manufactured in the system itself.
- To modify/adapt transferred MMC.
- To start with less complex methods and products.

In the first scenario, transferred MMC may become far too expensive compared with prevailing methods of construction in Iran. In addition, such systems may not be flexible enough for future developments, which may increase the risk of failure in long term. The second option means applying regional/local materials and modifying the details and components to produce MMC which are suitable for the Iranian conditions. This will considerably increase the chance of success for MMC although it needs considerable initial investments as well as accurate planning and execution which may be costly and time consuming. The third option may be the most successful of all suggested scenarios as the methods and products are simple and do not require highly skilled labourers or heavy machinery and are easily combined with prevailing methods of construction. Examples are some internal and external walling, cladding and roofing systems such as compound walls and sandwich insulated panels etc.

It should be noted that it is a great mistake to assume that traditional methods should be completely replaced with industrial and modern methods of construction. In fact the history of the UK construction industry during the 20th century has shown that although the share of industrialised methods increased greatly, they were never able to replace traditional methods of construction. Traditional methods have always competed with the industrialised methods by increasing their efficiency through the use and application of new and enhanced methods, components, materials, and management. This was however not possible without creating a competitive environment in which traditional methods felt under increasing pressure/threat by the very popular prefabricated methods of construction. Iran should also prepare the ground for broader application of industrialised methods and create a competitive environment in which both traditional and innovative methods become more efficient and adopted by the Iranian construction industry.

4. Conclusions

This paper intended to study the feasibility of application of Modern Methods of Construction (MMC) in Iran. Several issues such as demand and supply; practicality; costs; energy conservation and waste reductions; regulations, policies and standards were studied and opportunities, challenges and risks were identified and discussed in detail. The results of this study revealed that, compared to the UK, the Iranian construction industry is immature in terms of efficiency and performance. Several modifications are required in order to minimise the associated risks of MMC in Iran. The chance of successful adoption is considerably higher for those MMC that are simple and suitable for small developers, do not require highly skilled labour and heavy machinery, and are compatible with prevailing methods of construction in Iran.

According to the findings of this work, the current demand for housing in Iran is about six times greater than in the UK, which could arguably be regarded as long term demand and low risk for MMC products. However, finished prices of MMC products are not clear since several criteria, which have the potential to save (e.g. less waste, cheaper materials and labour), or increase the costs (e.g. less industry capacity, transportation, economic instability) should be evaluated in more detail. Moreover, environmental advantages of MMC such as greater energy saving, higher quality and, consequently, longer lifespan would potentially help to reduce the environmental impacts and CO_2 emissions of the Iranian construction industry. However, there are concerns about CO_2 emissions from transportation as Iran is a vast country which suffers from inefficient transportation infrastructure.

It should be noted that MMC are very different from traditional methods of construction in terms of the associated risks and construction processes. Educating the stakeholders to become aware of the advantages and disadvantages of MMC would help to reduce the associated risks. Without considering such issues, MMC may not only fail to achieve their potential advantages but could possibly deteriorate the current situation. Yet, there are great opportunities for some MMC if abovementioned issues are considered and MMC are adapted to the Iranian requirements and conditions.

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