Note: This paper has been presented at CTM 2014 international conference. Please use the following to cite this publication:

Hashemi, A., Hadjri, K. (2014), Offsite construction, a potential answer to the Iranian housing shortages, Construction Technology and Management CTM 2014 International Scientific Conference, 9-11 September 2014, Bratislava, Slovakia, 189-199. ISBN: 978-80-227-4243-6

OFFSITE CONSTRUCTION, A POTENTIAL ANSWER TO THE IRANIAN HOUSING SHORTAGES

Arman Hashemi
Grenfell-Baines School of Architecture, Construction and Environment, University of Central Lancashire, UK.
AHashemi@UCLan.ac.uk

Karim Hadjri
Grenfell-Baines School of Architecture, Construction and Environment, University of Central Lancashire, UK.
KHadjri@UCLan.ac.uk

Abstract

The housing shortages are one of the greatest problems facing the Iranian government. Population growth, demolishing the old stock, inadequacies in the construction industry and destruction caused by natural disasters such as earthquake have resulted in a massive housing demand in Iran which is increasing year by year. Considering the current housing production in Iran, around 740,000 more residential units are required to be constructed annually to overcome the housing scarcities. For various reasons, traditional methods of construction have failed to answer the current demand. It is believed that advanced methods of construction can enhance the current situation and lead to a professional, dynamic construction industry resolving some of the housing issues in Iran. During the recent decades, several attempts have been made by the government and individuals to introduce modern methods of construction to Iran. Many of these have failed due to the lack of research and correct understanding of the Iranian conditions, potentials and limitations. This paper intends to firstly report on the current Iranian housing situation and secondly to investigate the relevance of offsite construction to housing shortages in Iran. Available literature on the Iranian construction industry and offsite methods of construction was studied and the findings were used to identify and analyse the risks and possible improvements if such methods were to be applied in Iran. The results reveal that there are potential benefits if offsite construction methods are applied in Iran; however, this should be based on comprehensive programmes/studies to avoid another failure as offsite methods enforce a different set of risks compared to traditional methods of construction.

Keywords: Offsite Construction; Construction Technology; Housing; Iran.

Introduction

With a population of more than 75 million (CIB, 2014b; SCI, 2012), and an area of over 1.6 million sq. km., Iran is the largest country located on the northern coast of the Persian Gulf. Iranian construction industry takes only 5% of the whole industry (CBI, 2014a) but being linked to several other sectors, it is very influential on the entire economy. The construction industry itself suffers from several problems including low productivity, insufficient housing output, skilled labour shortage, unprofessional small developers, material and energy waste, defective management, lack of reliable and up to date information in addition to many other deficiencies which should be addressed.

The current situation of the Iranian construction industry is to a great extent defined by its massive housing demand which has been increasing year by year. The Iranian government and especially the private sector have been engaged to answer to the high housing demand in the last four decades. Despite constant efforts of the government and the private sector the gap is increasing resulting in house prices being pushed up which in turn decreases the affordability of houses. It is estimated that 1.5 million residential units are required to be constructed by 2025 to answer the housing shortages (BHRC, 2009b). Meanwhile, the volatile economy significantly influences the Iranian housing market. Iranian economy is unstable and suffers from very high inflation (39.3%) and liquidity (CBI, 2014b) which affect the housing demand and supply considerably.

Considering the potential advantages of offsite methods of construction (CIC, 2013; Miles and Whitehouse, 2013; Myers, 2013; AMA Research Ltd et al., 2007; Burwood and Jess, 2005; NAO, 2005a; Post, 2003) the general belief is that the application of such methods will resolve some of the above issues in Iran (Hashemi, 2009; Sarabandi, 1995). This is while, according to Fatemi (2008) "less than 3% of constructed buildings in Iran are built using industrial methods of construction".

Several attempts have been made towards industrialization of the Iranian construction industry since the 1950's. Many of such attempts have failed due to the lack of research and adequate understanding of the Iranian conditions, limitations, and potentials. Various reasons have been mentioned for the failure of these methods in Iran some of which are as follows: (Hashemi, 2009; Amiri, 2001; Fallah, 2001)

- Shortage of heavy construction machinery
- Transportation facilities and infrastructure issues
- Shortages in skilled labour and experienced engineers, architects and managers
- The inability of the factories to meet the country's particular need
- Lack of appropriate regulation, standards and experience
- Low demand for mass-produced houses, due to sufficient output of the traditional methods.
- Heavy and inflexible products
- High costs
- Dull and monotonous products

This paper reports on the current situation of the Iranian construction industry and attempts to briefly define its requirements, shortcomings, and risks in order to investigate the relevance and potential of offsite construction methods to address the current housing shortages in Iran.

Several subjects such as the housing industry, demand and supply, construction methods, energy consumption, and offsite methods of construction have been briefly discussed. The results of the paper reveal several important potentials and risks, which should be considered in order to resolve the current housing crisis in Iran.

Methodology

This paper critically reviews relevant literature including books, papers, websites and technical reports published by individuals and governmental organisations and other research bodies. The analysed data along with the outcomes of the literature review are used to assess the current situation and to identify the critical factors in the Iranian construction industry. The potential advantages and risks of offsite construction are then discussed to evaluate the relevance of such methods to Iranian housing shortages and to investigate the potentials for improving the current housing conditions in Iran. The results of all sections are then used to draw some recommendations as the conclusion of this paper.

The Iranian Construction Industry

The Iranian economy can be divided into twelve key sectors (Figure 1). Construction industry stands for only 5% (CBI, 2014a) of the total GDP, 80% of which (based on the share of the construction areas) is accounted for by housing (SCI, 2013). The construction industry consists of public and private sectors where housing as the largest portion plays an important role. The characteristics of the Iranian housing are defined by rather high level of home ownership (62.7 %) and self-built housing, small builders, and domination of the housing industry by the private sector. In 2012/13, for instance, excluding the city of Tehran, around 92.5% houses in Iran were built by the private sector and only 1.1% by the government and 6.4% by housing co-operations. In Tehran the housing sector is also dominated by the private sector which has constructed 98% of the all houses compared to only 1.2% by housing co-operations and only 0.7% by the government during the same period (SCI, 2013).

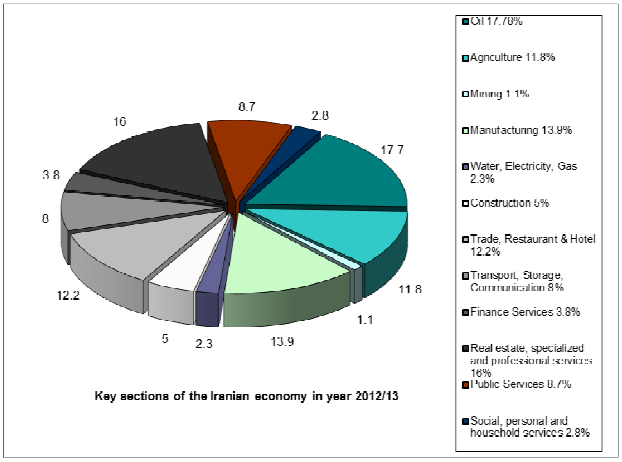

Figure 1: The share of GDP for each sector (imputed bank service charges (3.3%) should be deducted from the sum of the figures), Source of table: (CBI, 2014a)

Figure 2 shows the share of building certificates issued by municipalities for different building types in year 2012/13. Around 88% of all building permits in this year have been issued for residential buildings in different provinces of the country. Another 7% have been

issued for residential buildings mixed with workshops. Therefore, about 95% of all building certificates have been directly related to residential projects. The rest of the building types including industrial, educational, commercial and health care, accounted for only 5% of all the construction projects.

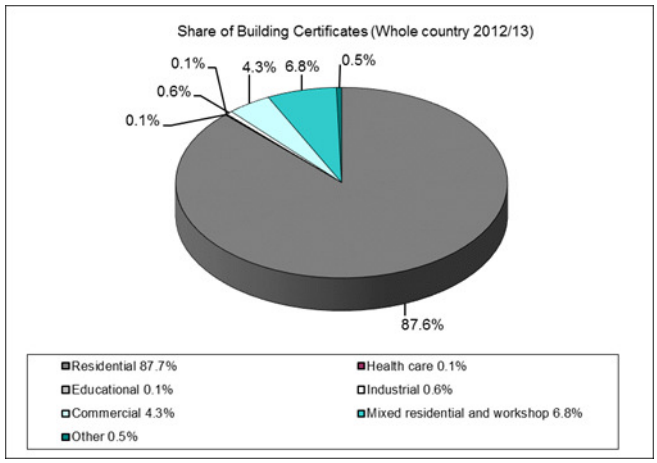

Figure 2: Share of building permits based on building types (2012/13). Source of table: (SCI, 2013)

The Iranian Housing Condition

According to the latest census published by the Statistical Centre of Iran SCI (2012), in 2011, there have been 21.05 million families living in 19.9 million residential units, which means a shortage of 1,150,000 housing units. In addition, on average, 738,000 new families are added every year to the population. Also, according to the SCI (2013), the housing production in 2012/13 has been around 761,000 units 167,000 of which were replacements for the existing stock in the urban areas. Therefore, to answer the current need in a period of ten years, there should be 1,020,000 (738,000+167,000+ (1,150,000/10)=1,020,000) units per annum which means the housing output should increase by 259,000 residential units. This is while, according to BHRC (2009), 1.5 million housing units are required by 2025 which means a shortage of 739,000 per annum based on 2012/13 housing production figures. It is obvious that achieving these figures is almost impossible by only relying on the prevailing/traditional methods of construction.

Figure 3 shows the share of residential building permissions based on the number of storeys and number of units in Tehran 2012/13. The majority of residential units (93.5%) built in Tehran in 2012/13 are buildings with five or more storeys and around 52% of all constructed buildings have five or more units. About 99.5% of the constructed buildings have three or more storeys and only 0.5% are single storey houses which shows the popularity of flats in Tehran.

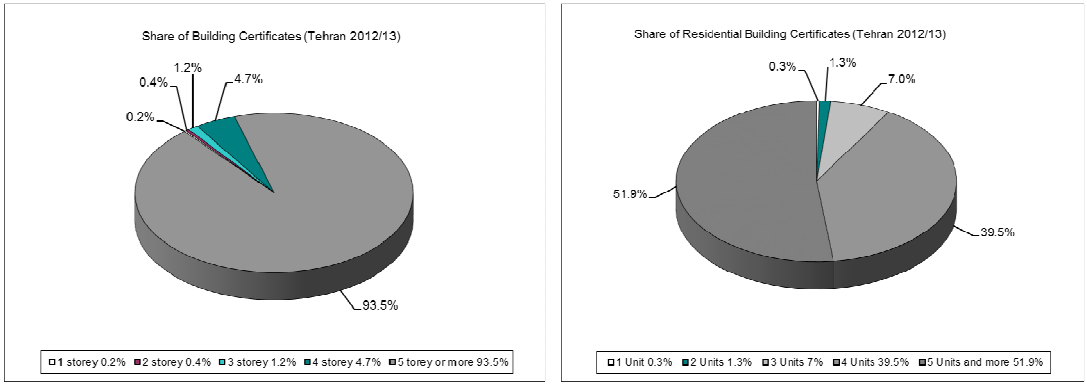

Figure 3: Share of residential building permissions based on the number of storeys and number of units in year 2012/13. Source of table: (SCI, 2013)

The situation is rather different when considering the whole country since around 26% of the building permissions have been issued for single storey houses and 35% for single unit houses. Around 53% of the building permissions have been issues for residential buildings with three or more storeys. Although not comparable with Tehran, it still is a considerable portion of the whole residential buildings which shows the popularity of flats in the country. It should also be mentioned that about 31.7% of all building permits in the country in 2011/12 have been issued in Tehran which shows the weight of this province in the Iranian housing market (SCI, 2013).

Current Methods of Construction in Iran

Reinforced Concrete (RC), Steel, and Brick & Steel are the most common construction methods in Iran. RC system with 52% and steel frame with 29.5% are the leading construction methods (Figure 4) followed by Brick and Still (17.7%). The other methods of construction including concrete block systems have very small portion of the whole construction industry.

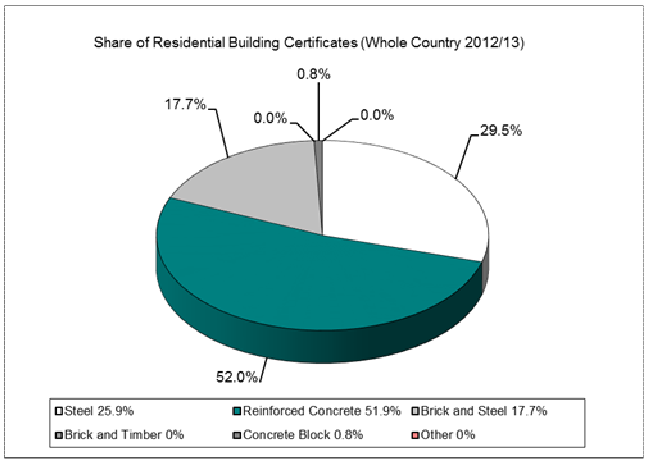

Figure 4: Share of residential building permits based on building materials and the structure in year 2012/13
Source of table: (SCI, 2013)

According to the published data, in 2007, 37% of the building permits were issued for construction of steel frame buildings, 38% for reinforced concrete, 22% for steel and brick, and 3% for other methods of construction (SCI, 2008). Additionally, the information published by the government in 2009 shows that RC systems with 39.9% and steel frame with 33.4% are the leading construction methods in Iran (SCI 2010). These figures show a rather stable trend in the share of steel frame to RC systems during the recent years (Figure 5); however, the trend of using these two methods has in general been upward.

Figure 5: Construction methods in Tehran (RC frame); Source: the authors

Earthquake, Material Waste and Energy Consumption Issues

Iran is situated on a Himalaya-Alps seismic belt which means that earthquake must be a concern in the construction process. Every year there are two to three major earthquakes in Iran, which cause a massive destruction. Based on the available statistics every year there is an earthquake of six on the Richter scale and every few years a deadly earthquake that is more than seven on the Richter scale. In Tehran region alone, every month there are about 50 earthquakes of 2 to 4 on the Richter scale (Mokhtari, 2004).

The reasons for such disastrous destructions in recent earthquakes are the use of low quality materials and that the majority of residential buildings are not earthquake proof. It seems that due to the poor workmanship, conventional methods of construction in Iran are not very reliable to build earthquake-proof buildings. Even if all earthquake rules are considered in design and structural calculations, applying conventional methods along with human interference in installation of structural elements such as welding and concrete works, makes it rather difficult to have a high quality structure. Even if a building has a tiny structural problem, it will be damaged from that specific area in the event of the earthquake (Figure 6).

Figure 6: Human interference could increase the risk of defects, Source: the authors

Another problem of the Iranian construction industry is considerable construction material waste on site (Figure 7). Around 20% of construction materials are wasted in Iran compared with 5% waste in developed countries (Shakeri, 2004). Energy efficiency is another concern in the Iranian construction. The average energy consumption in housing sector in Iran is estimated to be around 2.6 times more than international standards (Khalili, 2004). Energy efficiency regulations became compulsory in all buildings in urban areas from 2010 (IFCO 2014) which has helped to reduce energy waste in the housing sector. Energy consumption over the past two decades in Iran has increased by an average of 6.1%. In 2007 housing, public, and commercial sectors were accounted for around 41.1% of the entire energy consumption in the country (Shabani et al., 2008). The critical situation in terms of energy performance in housing sector becomes more evident considering the fact that in 2011 only 8.5% of houses in Iran had double glazed windows and 6.2% had external insulated walls (SCI, 2011). Moreover, the average energy consumption of Iranian people per head is around 1.5 times higher than the average world's standards (Shabani et al., 2008).

Figure 7: Construction material waste in Iran, Source: the authors

The energy waste during the construction period is also a major problem of the Iranian construction industry. Only 30% of consumed energy, such as gas, electricity, and water, is

used efficiently during construction process in Iran and around 70% is wasted (Gharazi, 2004). These figures reveal the importance of application of appropriate regulations for the construction industry to avoid any further damages to the environment.

Discussions: Offsite Construction Methods, Potentials and Risks

Several issues such as housing demand and supply, construction methods, material and energy wastes, natural disasters and economic conditions were discussed in the previous sections which directly or indirectly affect the housing situation in Iran. Application of offsite methods could address many of these issues thanks to their advantages over traditional methods of construction.

There are several claimed advantages for offsite construction methods including higher speed of construction; better quality; improved health and safety; improved control conditions; need for fewer skilled labourers; less weather dependant; reduced waste and energy consumption; cost predictability; and enhanced value for money (CIC, 2013; Miles and Whitehouse, 2013; Myers, 2013; AMA Research Ltd et al., 2007; Burwood and Jess, 2005; NAOa, 2005; Post, 2003). In terms of the construction, offsite methods can be classified under five main categories of (Miles and Whitehouse, 2013; AMA Research Ltd et al., 2007; Burwood and Jess, 2005; NAO, 2005a; CABE, 2004; BRE, 2004):

- Panel systems (open & closed)
- Volumetric systems
- Pods (e.g. kitchen, bath)
- Hybrid systems (semi-volumetric)
- Sub-assemblies and components

Higher speed of construction is one of the major advantages of offsite methods over traditional methods of construction. According to a survey by CABE, speed of construction is the main reason for considering such methods of construction by designers (CABE, 2004). Offsite methods could, therefore, increase the Iranian housing output by accelerating the construction processes on site. Moreover productivity in the factory can reach to 80% which is as twice as the productivity for a typical construction site (Buildoffsite, 2012). Meanwhile applying offsite methods can considerably reduce the construction material waste (Buildoffsite, 2012; AMA Research Ltd et al., 2007). Table 1 shows the potential savings in wastes for offsite methods compared to traditional methods of construction. Reduction in construction material waste not only benefits the environment but also improves the housing production in Iran. It is estimated that 120,000 houses could be constructed in the country if construction material waste is reduced in Iran (Shakeri, 2004).

Table 1: Waste reduction potential of offsite methods of construction (AMA Research Ltd et al., 2007)

Waste reduction potential of offsite methods of construction	
Offsite Method	**Estimated Waste Reduction**
Volumetric Systems	70-90%
Structural Insulated Panels	50-60%
Precast Cladding	40-50%
Pods (Kitchen, Bath)	40-50%
Precast Floor Systems	30-40%
Timber Frame System	20-40%
Concrete Panel Systems	20-30%

Higher quality and fewer defects are the other advantages of offsite methods (Table 2). In the UK, for instance, there is considerable number of defects in houses built with traditional methods of construction. Developers may need to spend up to £2,000 to resolve the problems such as damp proofing. Applying offsite methods can decrease such faults and decrease the risk of defects caused by the human errors and site conditions thanks to the factory quality control processes. This is particularly important considering such defects could damage the buildings in the event of earthquake in Iran. Applying offsite methods however increases the risk of hidden faults which may be repeated several times in many houses (Post, 2003).

Table 2: Snagging as a percentage of building costs (NAO, 2005b)

Snagging as a percentage of building costs			
Brick/Block	**Timber Frame**	**Advance Panel**	**Volumetric**
35%	2%	1.5%	0.5%

One of the major barriers towards broader application of offsite methods is their extra immediate costs compared to traditional methods of construction (Miles and Whitehouse, 2013; BRE, 2004; CABE, 2004). However, offsite methods offer some financial benefits such as earlier rent and shorter borrowing periods thanks to their higher speed of construction compared to traditional methods (NAO, 2005b). Although currently the figures are suggesting higher costs for offsite products, according to NAO (2005a) there is potential cost reduction of up to 15% if the industry is matured and if there is an available market for such methods. Furthermore, applying offsite construction decreases risks in some areas such as price fluctuation during construction process. Given the aforementioned unstable economy and very high inflation rates in Iran, this could be considered as a key advantage of offsite construction methods which could make these methods desirable in terms of costs and adaptability in Iran.

Conclusions

A massive housing demand is the major issue facing the Iranian construction industry. The majority of houses in Iran are constructed using traditional onsite methods of construction. However, material waste, poor quality, and substantial energy consumption have made such methods rather inefficient. The considerable housing demand and limited capacity of prevailing methods of construction have caused advanced methods of construction to be considered as a potential answer to the current housing shortages in Iran. It is believed that applying offsite methods of construction will resolve many of the abovementioned issues. The government is mainly encouraging the use of innovative method of construction for two main reasons: increasing the productivity of construction industry and decreasing the number of disastrous destructions caused by earthquakes.

It could be argued that efficient production, optimum use of materials and resources, higher quality, and faster construction are the most relevant advantages of offsite methods of construction for the Iranian housing conditions. Compared to traditional methods, applying offsite methods helps to have stronger buildings with longer lifetime and fewer defects thanks to their higher quality due to the factory quality control processes. Moreover, thanks to their less material waste and faster construction processes, offsite methods can help to increase housing production in Iran.

Yet, studies show that some previous attempts to import prefabrication factories have been less successful due to several reasons including complexity and inflexibility of their products as well as the lack of proper infrastructure in Iran. Therefore, any new attempts to introduce new methods of construction to Iran should consider such limitations to avoid repeating the previous mistakes. Moreover, it should be noted that compared with traditional methods, offsite methods enforce different kinds of risks such as late design changes; loss of factory production; manufacturer insolvency; and planning issues (NAO, 2005a). Considering such risks are crucial toward successful application of these methods of construction.

Further research about other issues should evaluate the viability of offsite construction in Iran. These include the building regulations and standards, practicality, costs, design, sustainability, policy and planning, pioneers, education and construction management. These issues need to be studied in more detail to identify the requirements and limitations as the likely success or failure of offsite construction is directly related to the above criteria.

References

AMA Research Ltd, Hartley, A., Blagden, A (2007) Current Practices and Future Potential in Modern Methods of Construction. WAS003-001: Full Final Report, Oxon: Waste & Resourcesn Action Programme.

Amiri, S. Y (2001) A Study Of The Production of Prefabricated Units For Industrial Building Systems In Factories In Iran. PhD Thesis, Sheffield, University of Sheffield.

BHRC (2009) New Construction Technologies (5th ed.). trans. Tehran: Ministry of Housing and Urban Development of Iran, BHRC.

BRE (2004) Modern Methods of Construction. Off-site construction – for and against. Watford: Building Research Establishment.

Buildoffsite (2012) Buildoffsite Review 2012: The business case for offsite. available at: http://www.buildoffsite.com/pdf/Yearbook/bos_yearbook_2012_54pp.pdf

Burwood, S., Jess, P (2005) Modern Methods of Construction: Evolution or Revolution? London: BURA Steering and Development Forum.

CABE (2004) Design and modern methods of construction: review. Research outcomes: 5. London: Commission for Architecture& the Built Environment.

CBI (2014a) Annual Review 1391 (2012/2013). In Economic Research and Policy Department, Public Relations Department, Tehran: Central Bank of Iran.

CBI (2014b). Economic Trends No 74, Third Quarter 1392 (2013/2014). In Economic Research and Policy Department, Public Relations Department, Tehran: Central Bank of Iran.

CIC (2013) Construction Industry Council, Offsite Housing Review February 2013, Ed. Miles, J., and Whitehouse, N., London: Construction Industry Council.

Fallah, M. H (2001) Potential Use of Light Steel Framing for Residential Building Construction in Iran. PhD Thesis, Sheffield, University of Sheffield.

Fatemi Aghda, M (2008) "Less than 3% of the country's construction projects are industrial", trans. available at: http://shasa.ir/newsdetail-48201-fa.html

Ghanbari, P (1989) The interaction of planning policies and construction technologies. PhD Thesis, Newcastle Upon Tyne.

Gharazi (2004) "70% of energy in construction process is wasted." trans. Special News of Construction and Housing, No. 50. Iran Construction Information Centre.

Hashemi, A (2009) Construction Technology Transfer: An assessment of the relevance of Modern Methods of Construction to housing shortages in Iran. Ph.D. Thesis, Cardiff University, Cardiff.

IFCO (2014), "Some Clarifications Around the Title 19 of National Building Regulation", Iranian Fuel Conservation Company, available at: http://ifco.ir/building/mabhase19/mabhase19_desc.asp

Khalili, M (2004) "Energy consumption optimization in buildings will become mandatory in 8 years." trans. Special News of Construction and Housing, No. 47. Iran Construction Information Centre.

Miles, J., Whitehouse, N (2013) Offsite Housing Review February 2013. London: Construction Industry Council.

Mokhtari (2004) "There are 50 earthquakes of 2 to 4 on the Richter scale every month in Tehran." trans. Special News of Construction and Housing, No. 50. Iran Construction Information Centre.

Myers, D (2013) Construction Economics: A New Approach (3rd ed.), Routledge, Oxon.

NAO (2005a) Using modern methods of construction to build homes more quickly and efficiently. London: National Audit Office.

NAO (2005b) Whole Life Costs. NAO MMC Study. London: National Audit Office.

Post (2003) Modern methods of house building. (Postnote, Number 209). Parliamentary Office of Science and Technology.

Sarabandi, B (1995) "Practical measures in mass building." trans. Housing Development Policies in Iran, The third seminar. Tehran, Ministry of Housing and Urban Development.

SCI (2008), Information of building certificates issued by municipalities for construction in urban areas 2007. Statistical Center of Iran.

SCI (2010), Information of building certificates issued by the municipalities 2009. Statistical Center of Iran.

SCI (2011), Results of household energy consumption in urban areas 2011, Statistical Center of Iran.

SCI (2012), Selected Findings of the National Population and Housing Census 2011, Statistical Center of Iran.

SCI (2013), Information of building certificates issued by the municipalities 2012. Statistical Center of Iran.

Shabani, N., Rezaei Ghahroodi, Z., Ghaderi, S., Abbasi, S., Haghighu, A (2008) Improving the Consumption Pattern, First part: Energy. Statistical Center of Iran.

Shakeri, A (2004) "120,000 housing units can be constructed every year using building material waste", trans. Special News of Construction and Housing, No. 52. Iran Construction Information Centre.