



A STUDY ON BAM EARTHQUAKE RECONSTRUCTION: AN EXPERIENCE IN URBAN SCALE EARTHQUAKE RECONSTRUCTION

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ABSTRACT

This paper is about the Bam City reconstruction after the 2003 earthquake. Bam is a small city which has many date palm and orange gardens and also due to the Arge-e-Bam is one of the tourist attraction centers in Iran. This reconstruction is a rare experience in urban scale reconstruction in Iran since it was based on a planning process and on-site construction. Social, cultural and environmental aspects were emphasized and also economy revival was important. There were some challenges in reconstruction implementation such as unfamiliarity with the environment, short time frame for reconstruction, and private lands. Based on this experience, safety improvement, resources conservation, compatibility with the context, applicable policies and community participation are important in sustainable urban reconstruction.

Introduction

This paper addresses post-quake reconstruction in Bam City following the 2003 earthquake and is based on studies undertaken in the City. Bam Earthquake reconstruction and recovery contains useful guidelines for urban scale reconstruction.

The goal of the paper is to show how reconstruction has been implemented in this case in order to issue some guidelines for reconstruction at urban scale.

The method of this paper consists of four sections as follows:

1. An overview of Bam City, its characteristics (natural, physical, social and economic). This section's information is based on national statistics and public reports about Bam City.
2. The earthquake features and damages in Bam City are presented. This section's information is based on official documents and field visits in Bam City.
3. Post-quake activities and plans in Bam City, the emergency and temporary settlement in the City, reconstruction outline and activities are discussed. This section's information is based on the official documents and the City visits.
4. Based on the previous sections information, Bam City's reconstruction is discussed and some guidelines will be issued.

This paper provides guidelines for reconstruction planning toward sustainability in cities. Protecting the cities identity and history during reconstruction is very important in urban sustainability.

Overview of Bam City

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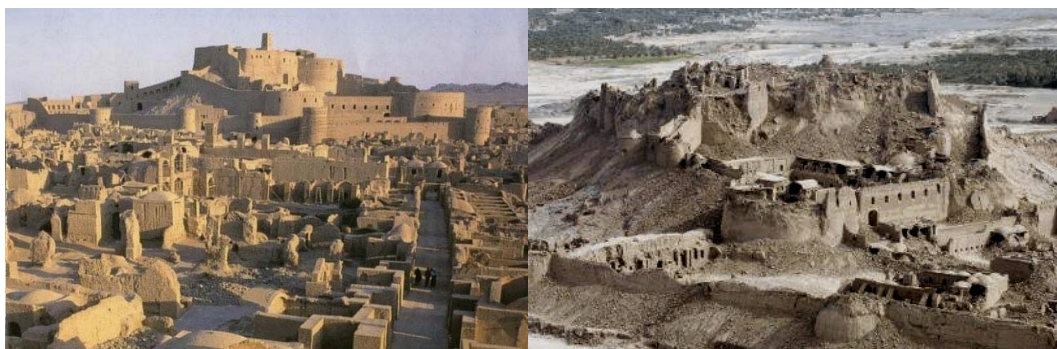
Bam is a small city in south eastern part of Kerman Province located approximately 200 km southeast of Kerman City (the capital of Kerman Province). Map. 1(Hisada et al. 2005)



Map 1. Bam City situation in Kerman Province and in Iran.

Apart from the adjacent city of Baravat (population about 15,000) and some settlements scattered in the neighboring area, it is surrounded by a sweep of desert. (Iran CAO) The city's square is about 20000 km² and its population is about 100,000 people (only city). The main active economic sections in the city are agriculture and gardening. The city has very large orange and date palm gardens. There are several underground water sources that are used as Qanat. About 51.5% of the City's water is provided through Qanats. (Housing Foundation 2004)

Arge-e-Bam (Bam Citadel) is a historical monument with 2500 years old. It is located in the northwest part of the city. This monument was an example of a typical Iranian large urban complex of ancient earthen architecture in an arid environment and one of the tourist attraction centers in kerman Province. Arge-e-Bam was heavily damaged by the 2003 Bam earthquake. The level of destruction was about 70% on major parts of this huge monument. Photos 1 and 2.



Photos 1 and 2. "Arge-e-Bam in before and after the earthquake"

Earthquake Characteristics and Damages

On December 26, 2003 at 05:56 (local time), a devastating earthquake of $M_w=6.5$ occurred in South-West of Bam City. The hypocenter of this earthquake was located at 29.01°N , 58.26°E , at a depth of 10 km in the south-west of Bam City as shown in Fig. 1 (Nakamura et al. 2004). Teleseismic focal mechanisms show a steeply-dipping, right lateral strike-slip fault. This earthquake caused catastrophic damage to the Bam city and neighboring villages with a collective population of about 142,000. More than 26,000 people were killed, 30,000 injured, up to 75,000 left homeless, and 85% of the housing and infrastructure were destroyed. Fig.2 shows map of Bam and Baravat cities, together with the location of newly identified causative Bam fault located in 3 km west of old Bam fault (Ghayamghamian and Hisada 2007). The figure also shows an earthquake damage map in the background, which was estimated during damage survey (Hisada et al. 2005). The eastern side of Bam City, which is closer to the northern segment of new Bam fault, shows higher damage rates than those of western side of the city. Furthermore, a heavy damage zone in the east of Bam can be observed where the northern and southern segments of new Bam fault connected.

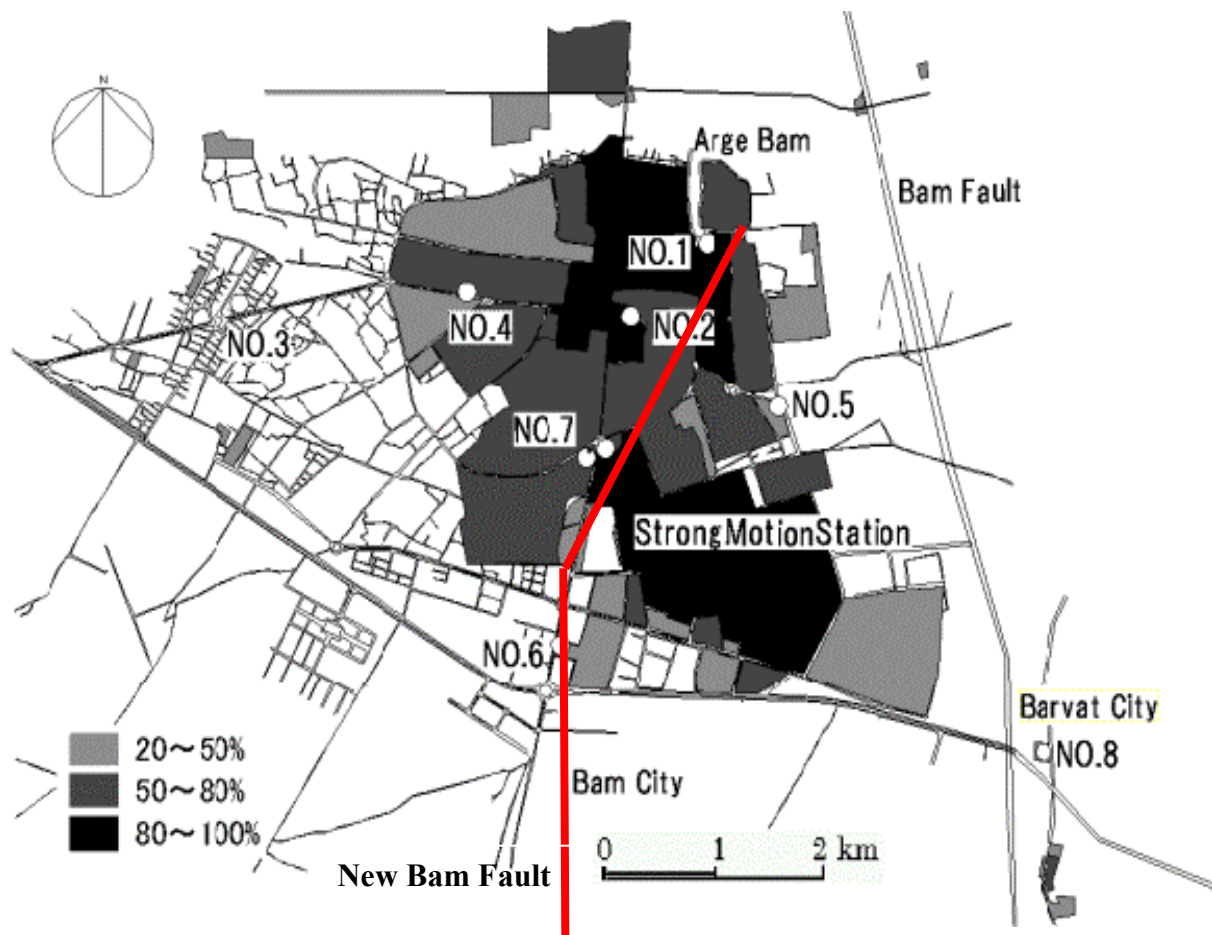


Figure 1. Map of Bam City with the distribution of earthquake damage on the background, and locations of old and new Bam faults

The volcanic hills outcrop at the north and southwest of the Bam City and are composed of Grano-diorite rocks. Most of the Bam City is located on the Quaternary alluvial soils. According to the conducted geophysical survey (Jafari et al. 2004), the depth of engineering bedrock (with shear wave velocity 650-750 m/s) varies between 5 to 37 m in the area. The Quaternary alluvial soils mostly consist of fine sand and silt as well as coarse grain gravel deposits of flooded plains. Arg-e-Bam is the only site where a rock is outcropping.

This outcrop consists of Andesite and Basalt without considerable effects of weathering. Fig 2.

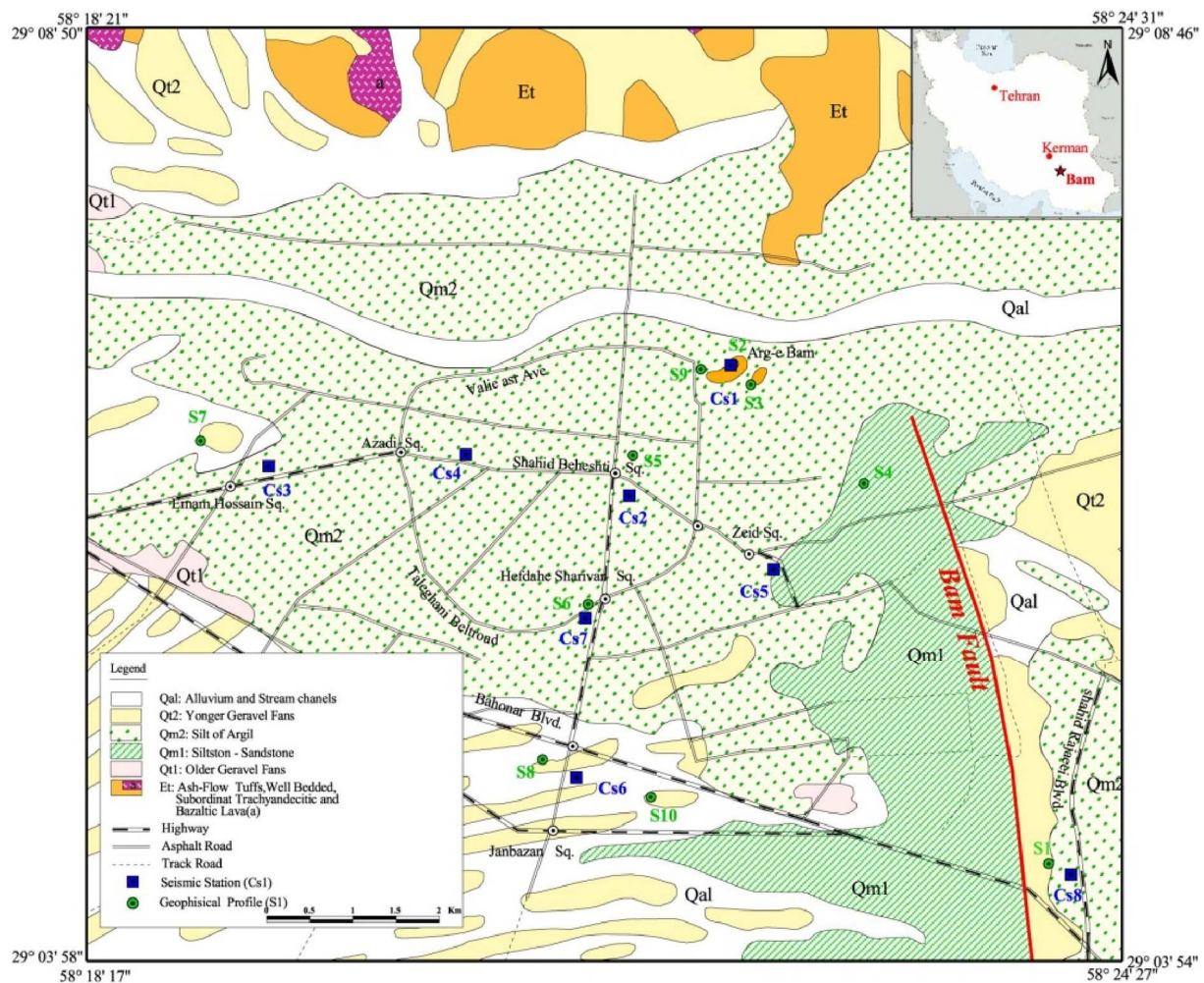


Figure 2. Geological map of Bam City

Emergency and Temporary Settlement

Due to high damage to public buildings and schools, these buildings could not be used as shelters, so emergency and temporary settlement were held in tents and prefabricated



Photos 3 and 4. Tents had been located near the destroyed houses

houses. Since there were many people whose houses were destroyed and because of limitations in preparing temporary houses, people had to live in tents for several months. (Khazai et al. 2005) The tents had been located near destroyed houses based on people's wishes (Photos 3 and 4), So they could protect their properties and also could use the facilities provided by the government. Some people moved to the camps that were created by the Red Crescent, but these camps mainly occupied by the tenants and immigrants from neighbor villages to Bam.

Living in tents for a long time had many difficulties and caused problems for people, such as:

- Due to climatic situation in the region with cold winters, hot summers and dessert storms with sand, it was very difficult to keep tents warm or cool.
- The temporary baths and toilets caused unsuitable hygienic conditions. Some people pitched their tents near schools in order to use the schools' facilities.
- Safety and security for residents in the tents, especially for tents resided in by only women and children, was an important problem.
- Due to the existence of insects and bacteria in the environment, in some areas there were stings and skin problems. The Red Crescent did insecticide actions to combat insects.

The other types of temporary houses were prefabricated houses in camps and also near destroyed houses. The primary decision was to construct the majority of temporary houses in the camps outside of the City. But because of residents' and local authorities' objection, it was decided to construct 10,000 residential units in the camps. These camps were mainly occupied by the people who had come from other places. Based on the statistics about 36,000 temporary houses were constructed in the Bam City, and about 9,000 units constructed in the camps around the City. More than 3,000 units in the camps were vacant and people didn't move into them. (Khazai et al. 2005)

Although living in temporary houses was better than living in tents, there were some problems in these houses, such as:

- Providing infrastructural services such as drinking water, electricity and telephone restoration.
- Shortage of hygienic facilities such as bath and toilets in temporary houses.
- Shortage of educational and welfare facilities such as schools, health centers, library and playgrounds in the camps.
- The temporary shelters were not suitable for the hot and dry climate of the Bam City. In the camps' environment there was no green space and lack of trees intensified the situation. The temporary shelters in the private lands were better because they had been located inside the gardens with trees and their shadows created much favorable environment.
- The camps had been established without considering social and cultural issues. Common use of baths and toilets and also privacy protection were serious matters. People used curtains to separate spaces. In general, neglecting cultural issues caused daily problems in the camps.
- There were Legal problems on land ownership and the construction permission would be issued if the person could present ownership document. Because of many owners' death and documents lost, ownership proof was very difficult and complicated.
- Many temporary houses were located on the private lands near destroyed houses. This situation caused secondary problems in debris removal and permanent construction.
- Long term use of temporary shelters in camps by tenants and immigrants made it very difficult to evacuate the camps since residents had no private land.
- Some people received tents and some other received prefabricated houses for temporary

settlement. Due to the obvious differences between these types of settlements a feeling of discrimination was created among people.

Reconstruction

Reconstruction Plan

Bam reconstruction was based on a planning process that was the first case in reconstruction experiences in Iran. This planning process originates from the Comprehensive Plan of Bam City. The Ministry of Housing and Urban Development assigned the construction work to the Armanshahr Consulting Company as contractor. (Armanshahr 2004) According to the reconstruction plan to protect the natural environment, historical sites and structures, the least changes should be done in the physical and spatial layout of the city. This indicates that the transportation routes are not widened and the city's social and cultural characteristics should be protected. Therefore, on site construction was the main strategy during reconstruction and relocations were prevented. This idea was based on the cultural and ecological priorities during reconstruction. (Behzadfar 2005)

Another important feature in this experience was reviving the economy. The agriculture and gardening sectors could rehabilitate quickly due to the existence of palm and orange trees. To rehabilitate the business sector, some projects were defined and about 4000 commercial units were identified. (Bhzadfar 2005)

But there were some problems in the reconstruction plan such as:

- Earthquake disaster management and damage reduction didn't take into consideration as much as other matters such as socio-cultural issues. Except than considering distances from seismic faults and permitted land-uses near faults, other issues such as building density, location and the distribution of necessary infrastructures for disaster management like traffic routes, hospitals and rescue-relief stations weren't taken into consideration.
- The time frame for the reconstruction, considering the amount of work, was rather short and construction inside the city had many challenges. (Housing Foundation 2006)
- Possession of the private lands located among main traffic routes was another problem. The Municipality approved about \$50 million for this purpose, but the land owners believed that the prices were not based on the real prices in pre-earthquake period. After the event, in some areas the land prices were decreased due to introducing the earthquake faults and in some other far areas from the faults the prices increased. The real estate agencies had forecasted land prices would increase during next few years so the land owners were reluctant to assign their lands to the Municipality. (Architecture 2004)

Reconstruction Policies

Different policies were considered in Bam reconstruction, such as: (Housing Foundation 2004)

- Policies on construction management and community participation: The construction management of damaged houses was assigned to owners and the Housing Foundation was responsible for technical assistance and material provision.
- Financial policies: including provision of loans with low rate of interest to construct earthquake resistant housing units, gratuitous aids and public investment in technical services such as debris removal, materials provision, construction supervision etc.
- Policies on housing square: based on reconstruction plan approval, financial aids were allocated to construct 80 square m² in cities and 60 square m² in rural areas.

- Policies on construction technology: including design standards codification to improve quality of construction by the Housing Foundation, recognizing local capabilities in damaged areas and presenting practical methods to promote construction technology in damaged areas.
- Policies on production of construction materials: these policies were based on local sources. So these policies would be applicable for native labor, economically would be reasonable and environment would be sound.
- Policies on organizational and bureaucratic matters: these policies include population distribution in cities and villages, avoiding parallel activities by different organizations and accelerating bureaucratic affairs.
- Policies on design and planning: these policies include preserving native designs and standards and restraining any relocation or integration without technical reasons.

Executive Organization of the Reconstruction

The main constitution for planning and policy making was "Bam Reconstruction Guiding Task Force". The task force members were the authorities of the responsible organizations. The main activities of the task force were promoting community participation, creating suitable situation for scientific and technical institutes to participate in reconstruction and improving the construction quality in the affected areas. (Hassani 2004)

Four working groups were organized by the task force to facilitate its responsibilities. These working groups were:

- Provision and goal setting for public and donated aids;
- Provision and goal setting for international aids;
- Plan formulating and design making for Bam Reconstruction;
- Organizing Bam provincial reconstruction task force (including the Governor of the Kerman Province and other responsible authorities).

The task force approvals were implemented by the Reconstruction Operational Task Forces during emergency relief period and during reconstruction by the auxiliary task forces that worked as the Housing foundation implementing forces. For reconstruction the offices of 16 Housing Foundations from different provinces formed the auxiliary task forces (10 in urban areas and 6 in rural areas) to start reconstruction operations and also to strength human sources in the affected areas and better logistics provision. These task forces were responsible for forming households' files, providing equipment, defining the housing boundaries, issuing construction permission and implementing all technical and executive standards. The task forces also guided people on how to receive loans and other financial aids. But due to unfamiliarity with the areas and the culture, there were some difficulties in communicating with people and this affected their function. (Moghimi 2004)

Reconstruction Implementation

Preparing implementation plans

To protect the City's identity, it was decided that qualified consulting companies to be settled in Bam City. These companies prepared the housing plans based on architectural and urban planning standards and considering the residents expectations. About 26000 plans were prepared for residential and commercial units. In general, 33 consulting companies settled down in Bam City. (Housing Foundation 2006)

Some residential units with less damage were investigated to get reinforced and about 1000 residential and 500 commercial units were reinforced. (Housing Foundation 2004)

Some training courses were held for construction employees such as native builders, contractors and welders by the reconstruction task force. (Housing Foundation 2006)

Debris Removal and Material provision

Immediately after the rescue and relief period, debris removal started in urban and rural areas. Since Bam reconstruction was based on on-site construction, the debris removal was important. For this purpose the Housing Foundation and other public and private organizations mobilized their machines. The most important matters in debris removal were as follows:

- The amount of debris was too much due to the under construction building types and the amount increased day by day.
- Environmental concerns on debris removal were at high levels during the first few weeks after the event.
- Some NGOs tried to teach residents on how to reuse remained construction material but time was very limited.
- Some houses had been located in the gardens inside the city so, debris removal was very difficult and some gardens were damaged as well.
- In debris burial, access to the areas and existence of open and vacant spaces had been taken into consideration. Other issues such as geological and seismological condition, Qanats' status, wind direction, population dispersion and natural resources in the area did not paid much attention.

It was estimated that 24 thousands tons of steel and 60 thousands tons of cement were necessary for reconstruction. Since the demands for construction materials have been increased a lot, 202 workshops were established in the area to produce sand, gravel, concrete etc. Twenty-three laboratories were created to control the quality of construction materials.

International organization's activities

Following the earthquake several international organizations entered the affected area in less than 48 hours. The Iranian Red Crescent Society was responsible for coordination and dispatching the teams. In general 34 search and rescue teams from 27 countries and 1800 people for relief from 44 countries entered the Bam City. Among the organizations there were WHO, UNICEF, UNOCHA, UNDP etc. The main activities of these organizations and individuals included: (WHO 2006)

- Medical and health services;
- Providing services for special groups like children;
- Constructing water tanks in affected area;
- Provision and dispatching necessary goods;
- Participating in schools and other educational institutes reconstruction;

The internal non-governmental organizations participated in different activities such as: (Zandrazavi 2005)

- Participating in immediate response activities like rescue, relief, temporary settlement and debris removal;
- Mental support for the affected people;
- Aid collection from different sources and distributing them among affected people;
- Design and construction of residential structures, schools, health centers, hospitals, university and sport center;

- Conducting educational activities in affected areas like holding training courses for school counselors, teachers, and social workers who work with orphans;
- Conducting cultural activities for people's rehabilitation.

Conclusion

This reconstruction experience had to deal with many challenges since urban scale reconstructions are very complicated. There were several positive aspects in this experience such as formulating reconstruction plan, on-site reconstruction and avoiding relocations, protecting the city's layout and its social and cultural characteristics, environmental concerns during reconstruction etc. But there were some aspects that need to improve like integrating earthquake risk management along with social matters in reconstruction plans, legal issues and realistic time frame.

One of the important parameters in time saving during reconstruction is using native sources (human /material) instead of outside sources that improves the sufficiency of the affected areas and avoids dependency on the outside. In Bam, unfamiliarity with the affected environment and culture by the task forces members caused delays in reconstruction.

Urban reconstruction is a multi-dimensional topic that due to urban environments characteristics has to be implemented in a comprehensive way with action-oriented policies while encouraging community participation and being replicable in future.

Based on this reconstruction experience the following guidelines for urban scale reconstruction are proposed:

- **Safety improvement:** all new programs and changes should be focused on safety improvement during reconstruction. In this case the quality of constructions and the long term consequences of changes are very important as improving safety is obtained through reducing vulnerability.
- **Resources conservation:** in reconstruction such as debris removal or evacuation, many resources could be damaged and their replacement will lead to increased spending for reconstruction. Preservation saves time, energy and human/capital resources which is very important during reconstruction.
- **Compatibility with the context:** this is very important in integrating social and physical aspects and attaining unique results. To achieve compatibility the patterns should be based on native background of areas and their sources.
- **Using native sources:** native sources such as native experts or the materials that are produced in areas or any other internal production are essential to be considered for reconstruction. The outside sources might not be continuous for a long time and it might cause delays in reconstruction.
- **Applicable policies:** reconstruction policies should be applicable by the residents and authorities in the stricken area; otherwise that will lead to dependency. Being applicable is a function of native sources, compatibility with context, and community motivation.
- **Public participation:** local level participation during reconstruction is very essential and the reconstruction policies should be discussed with the community before implementation. Community participation will facilitate plan approval and the process movement.
- **Sustainable outcomes:** programs selection should be based on the expected outcomes and how these outcomes affect the area over the long run. The important point is that the outcomes must be sustainable in order to conserve resources.

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