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UN HABITAT
FOR A BETTER URBAN FUTURE

EMERGENCY SUPPORT TO SAFER HOSPITALS AND SETTLEMENTS

A System-Approach to Seismic Design of Non-Structural Components in Hospitals

Afshin Kalantari
National Project Manager
UN-Habitat

UN-HABITAT Office in Tehran

- The United Nations Human Settlement Program (Habitat) strives for a better urban life. Habitat's mission is to promote the social and environmental development of human housing and infrastructure in human settlements to achieve the goal of housing suitable for the public. Habitat seeks to make the growth of cities and rural areas an opportunity for development by taking the lead in the process of urbanization and promoting change in policies, methods and attitudes to meet the needs of urban development; An all-encompassing opportunity for all citizens.
- The Un-Habitat Office in Iran, Tehran (UNHT) was established in 2009 with a focus on mitigating the effects of natural hazards and disasters and in accordance with an agreement between the United Nations Human Settlement Program and the Government of the Islamic Republic of Iran.

- **برنامه اسکان بشر ملل متحد** (**هبیتات**) برای زندگی شهری بهتر تلاش می‌کند. رسالت هبیتات ترویج و ارتقاء توسعهٔ اجتماعی و زیست‌محیطی **اسکان بشر** و دست‌یابی به هدف مسکن درخور برای عموم است. **هبیتات** می‌کوشد تا با پیشگامی در فرایند شهری‌شدن و ترویج تغییر سیاست‌ها، روش‌ها و نگرش‌های مقابله با نیازهای توسعهٔ شهری، رشد شهرها و مناطق روستایی را به فرصتی برای توسعه تبدیل کند؛ فرصتی فراگیر برای همهٔ شهروندان.
- **دفتر هبیتات در ایران** در سال ۱۳۸۸ با تمرکز بر موضوع کاهش آثار خطرات و بلایای طبیعی و بر اساس موافقت‌نامه‌ای بین برنامه اسکان بشر ملل متحد و دولت جمهوری اسلامی ایران تاسیس گردید.

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BEHTAB-I (2018-2020): Outlines

اهداف پروژه		
Improvement of Resilience of		
Existing health-care facilities	New health-care facilities	Network of health-care facilities in urban grid
روش شناسی		
Applying A Holistic Approach		
Multi-Hazard Analysis		RVA
Structural Assessment & Retrofit Design		Non-Structural Assessment & Retrofit Design
Functional Analysis		Urban-scale Analysis
Capacity Development Plan		Investment Plan
خروجی ها		
Delivering Various Outputs		
Safe Design Guideline		Investment Plans
Rapid Visual Assessment Web-application		Capacity Development and Trainings
Network GIS-based Resilience Analysis Tool		Case Studies' Report

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BEHTAB-II: Project Summary

Project Title	Emergency Support to Safer Hospitals and Settlements – BEHTAB Phase 2	
Donor	Government of Japan	
Partner	**Main Partner:** Ministry of Road and Urban Development (MoRUD)	**Implementing Partners:** Executive Organization of Public and Government Buildings (EOPGB), Road, Housing and Urban Development (BHRC)
Duration	30 September 2022	

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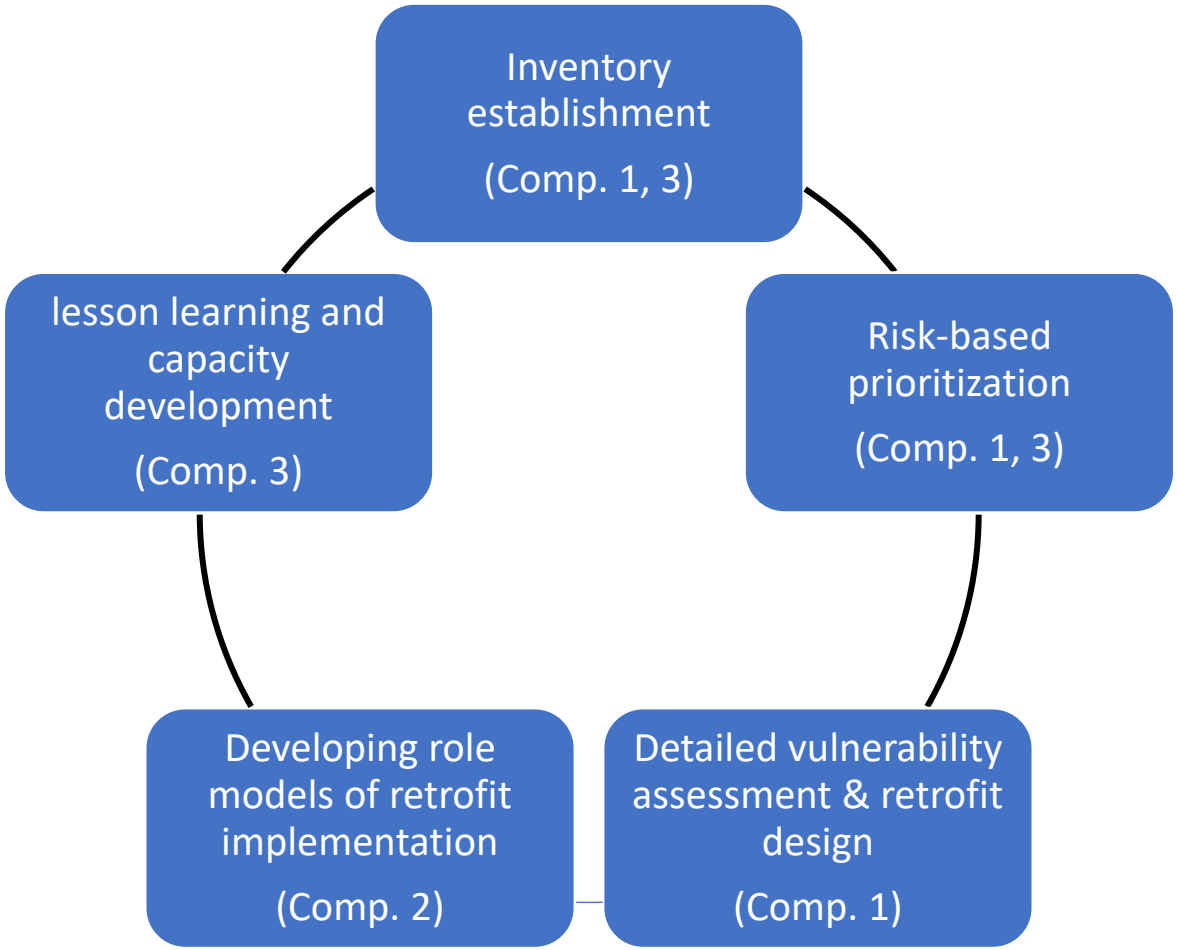
BEHTAB 2: A Risk-Based Approach



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Project components

Component 1	**Multi-hazard Assessment, Vulnerability Analysis and retrofitting design of constructed healthcare facilities such as hospitals, health centres and health houses**
Component 2	Demonstrating non-structural retrofitting construction of selected vulnerable hospitals and healthcare centres
Component 3	Capacity development of Government of I.R. Iran and related stakeholders

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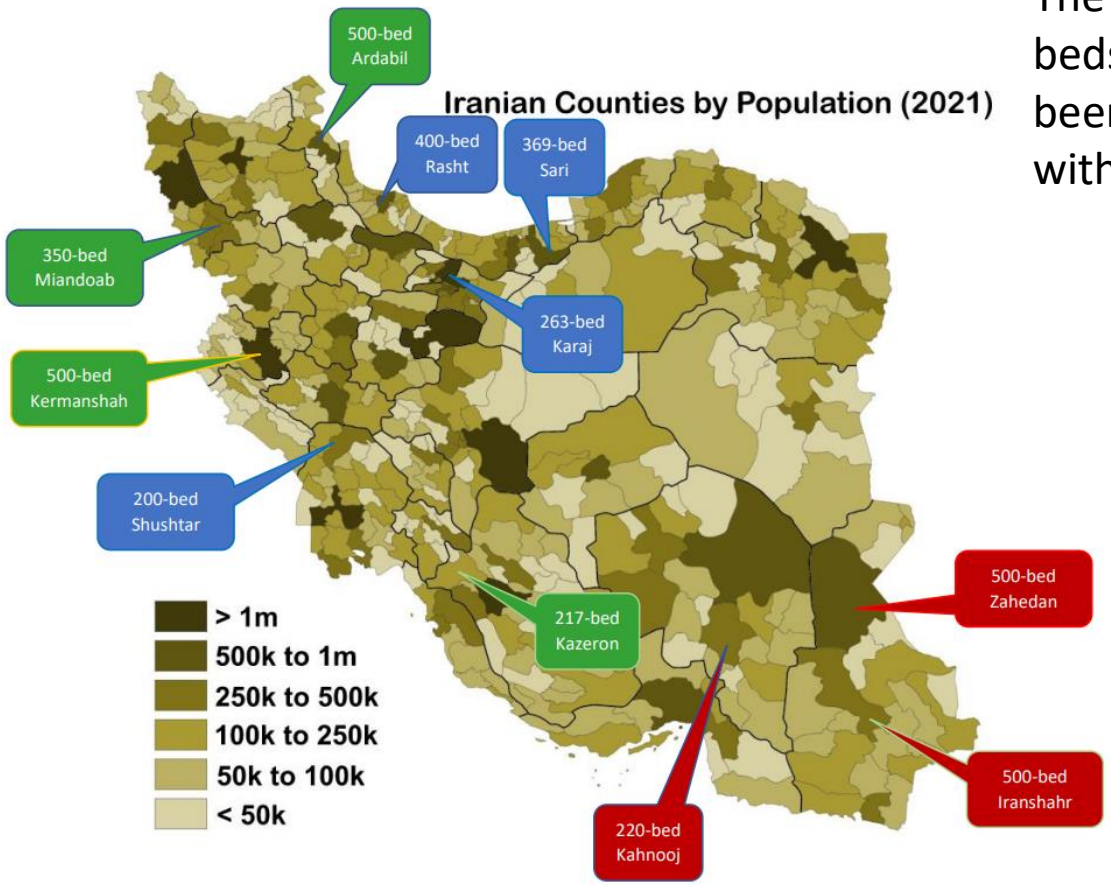
Component 1: List of Target Hospitals (Updated)

Province	City	No. of beds	Area (m2)
Alborz	Karaj	263	23,778
Mazandaran	Sari	369	28,338
Gilan	Rasht	400	37,426
Khuzestan	Shushtar	200	13,818
Ardabil	Ardabil	500	52,850
Fars	Kazeroon	217	17,800
Kermanshah	Kermanshah	540	56,473
Sistan & Ballochestan	Iranshahr	500	60,000
Sistan & Ballochestan	Zahedan	540	50,000
Kerman	Kahnooj	220	23,000
West. Az	Miandoab	350	31,000
SUM		4,099	394,483



The same number of beds and hospitals has been realized in project with the

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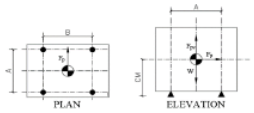
PROVIDING TECHNICAL DOCUMENTS: Development of Applied Material For Hospital Assessment & Retrofit Projects

Calculation Sheet Non-Structural Components

Component	The Air Compressor
Reference Analysis Code	Code 743
Reference Design Code	AISC360-16



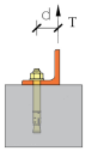
Input Data							L.S	I.O
A =	0.7	m	a_p=	1		B_s =	3.75	2.5
B =	0.7	m	A =	0.35		I_p =	1	1.5
CM =	0.75	m	W =	12	kN			
x/h =	0		R_p	2.5				

Design Forces	L.S	I.O		L.S Fp max	L.S Fp min	I.O Fp max	I.O Fp min
F_p	4.7	4.7	kN	25.2	4.7	25.2	1.7
F_{pv}	3.2	3.2	kN	3.2	3.2	4.7	3.2

Bolt Details								
n	2		R_{uv}	0.59	KN	$\phi F_{nv}A_{bolt}$	9.4	KN OK
ϕ	0.75	-	R_{ut}	2.22	KN	$\phi F_{nt}A_{bolt}$	17.7	KN OK
F_u	400	Mpa				$\phi F'_{nv}A_{bolt}$	9.4	KN OK
d_{bolt}	10	mm				$\phi F'_{nt}A_{bolt}$	17.7	KN OK

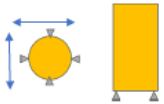
Connection Details

Try :	L100*8		
ϕ	0.9		
d	50	mm	
L	100	mm	
thk	8	mm	
Z	1600	mm^3	
M_u	0.22	KN.m	
$\phi F_y Z$	3.84	KN.m	OK Mu< $\phi F_y Z$



Calculation Sheet Non structural Components (Oxygen Generator)

Component	Oxygen Generator
Reference Analysis Code	Code 743
Reference Design Code	AISC360-16



Schematic Diagram & Geometric Data			
Dimension	A	0.68	m
	B	0.68	m
Center of Mass Elevation	C.M	1.62	m

Seismic Input Data			
Component amplification factor	a_p	1	
Acceleration	A	0.35	
Spectral Response Life Safety	B_s	3.75	
Spectral Response Immediate Occupancy	B_s	2.5	
Component Operating Weight	W	5	kN
Installation Height Ratio	x/h	0	
Component response modification factor	R_p	2.5	
Component performance factor Life Safety	I_p	1	
Component performance factor Immediate Occupancy	I_p	1.5	

Life Safety Performance Forces			
Horizontal Seismic Design Force	F_p	2.0	kN
Vertical Seismic Design Force	F_{pv}	0.7	kN

$$F_p = \frac{0.4\,a_p A B_s W_p}{(R_p/I_p)}\left(1+2\frac{x}{h}\right)$$

$$F_{pv} = \frac{0.27\,a_p A B_s I_p W_p}{R_p}$$

$$F_p = \frac{a_p A_s W_p}{(R_p/I_p)}$$

Immediate Occupancy Performance Forces			
Horizontal Component Seismic Design Force	F_p	2.0	kN
Vertical Component Seismic Design Force	F_{pv}	0.7	kN

Bolt Details			
No. of Bolts Each Pier	n	2	
Strength Reduction Factor	ϕ	0.75	-
Bolt Ultimate Tensile Strength	F_u	400	Mpa
Bolt Diameter	d_{bolt}	10	mm

Bolt Design Forces			
Bolt Shear Forces	R_{uv}	0.25	KN
Bolt Tensile Forces	R_{ut}	1.65	KN

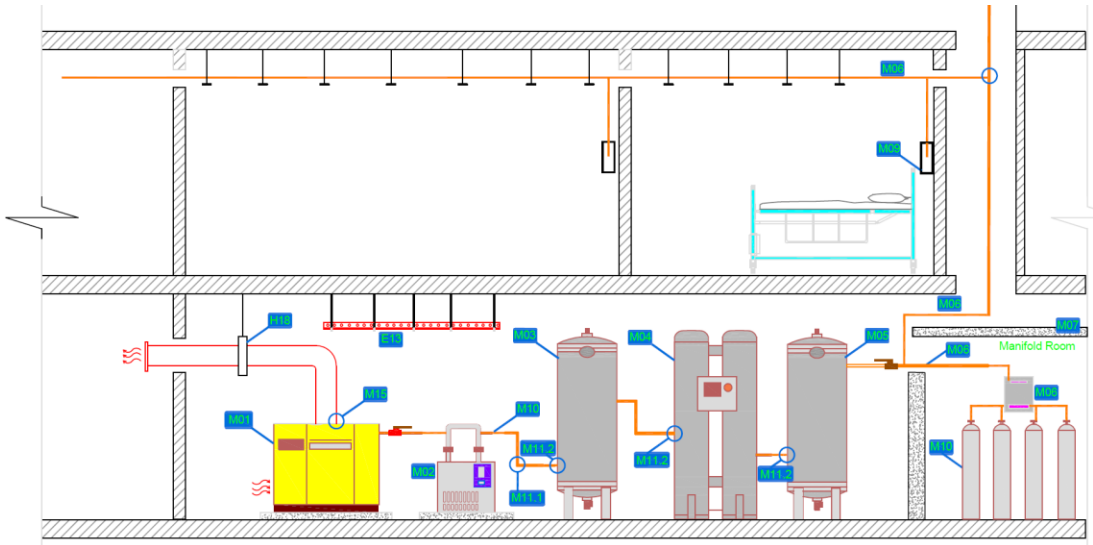
Bolt Design				
Design Shear Strength	$\phi F_{nv}A_{bolt}$	9.4	KN	OK
Design Tensile Strength	$\phi F_{nt}A_{bolt}$	17.7	KN	OK
Design Shear Strength	$\phi F'_{nv}A_{bolt}$	9.4	KN	OK
Design Tensile Strength	$\phi F'_{nt}A_{bolt}$	17.7	KN	OK

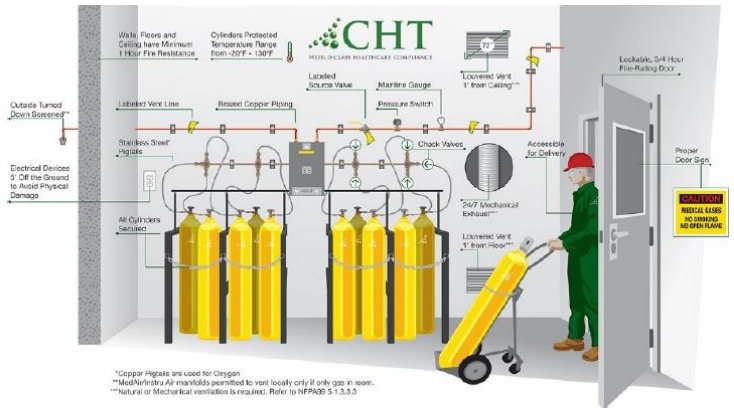
$$\phi R_{ut} = \phi F_{nt} A_b$$

$$\phi R_{uV} = \phi F_{nV} A_b$$

$$F'_{nt} = F_{nt}\left(1.3 - \frac{f_v}{\phi F_{nv}}\right) \le F_{nt}$$

$$F'_{nv} = F_{nv}\left(1.3 - \frac{f_t}{\phi F_{nt}}\right) \le F_{nv}$$





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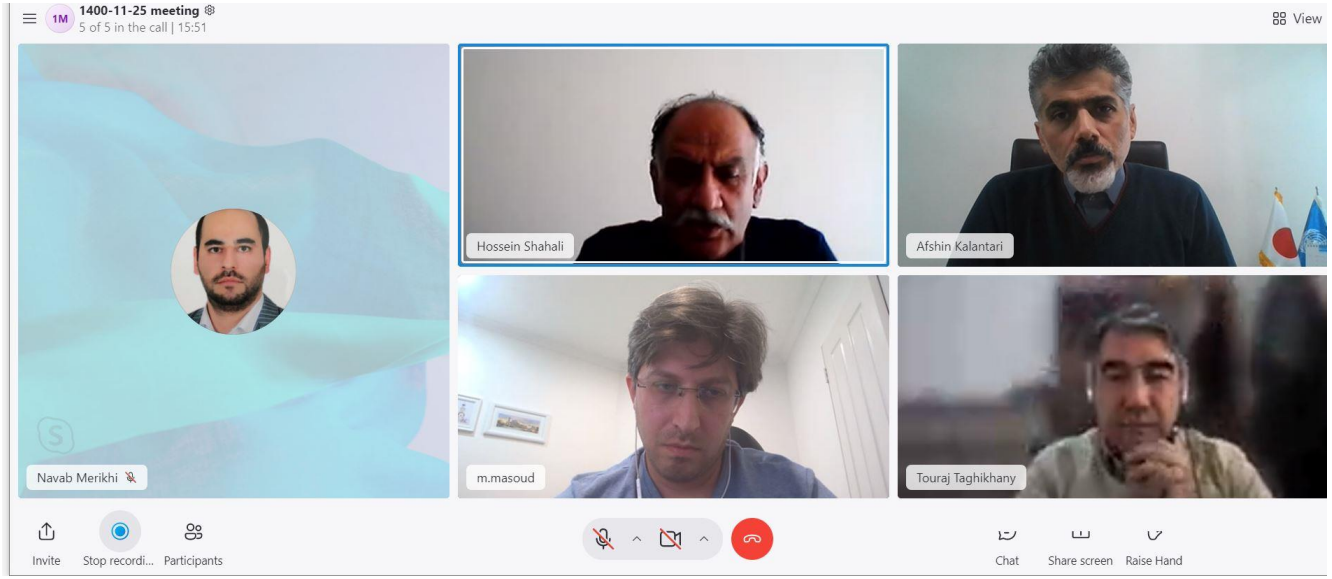
Promotion of Innovative Systems in Hospitals



- **Development of a Comprehensive Protocol for Implementation of ISDs In Hospitals**
- **Development of Descriptive Examples**
- **A national/international conference/webinar of application of seismic devices specifically in hospitals**

• Considering the general demands in the field of innovative technologies in the country and in order to meet the targets as defined in the project documents, the following actions have been taken:

✓ Providing a document regarding the current challenges in different managerial and directorial stages of health facility projects incorporated by innovative technologies (herein, base isolators) in the country.

✓ Organizing and holding a meeting with BHRC officials in order to find out their visions, points of view, and experiences regarding the application of innovative technologies in improving the resilience of hospitals

✓ Organizing and holding a meeting with PBO officials in order to find out their visions, points of view, and experiences regarding the current requirements in projects with application of innovative technologies for improving the resilience of hospitals

✓ Organizing and holding a meeting with Iran National Innovation Fund (INIF) officials for collaboration in supporting innovative ideas and developers

✓ Communication with some providers and consulting companoes

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BEHTAB Software – HRMAP platform

Development of:

HRMAP
HOSPITAL RISK MANAGEMENT PLATFORM

A GIS-Based Risk Management Platform

Inception Phase

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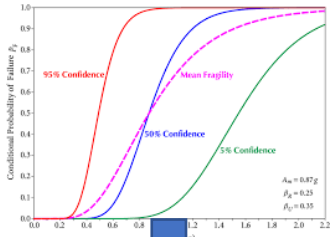
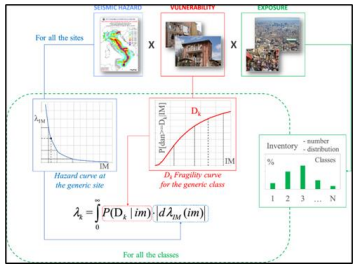
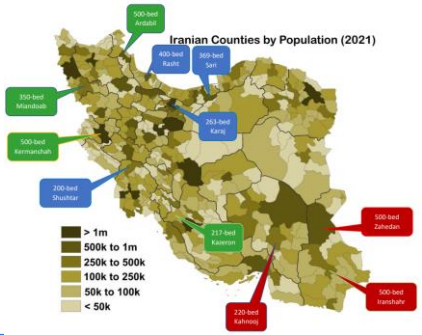
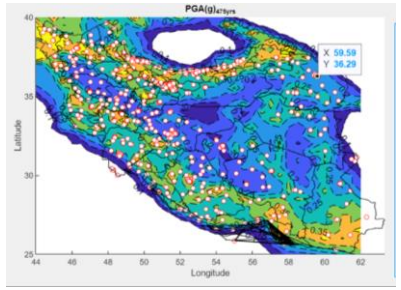
BEHTAB-II Software: Approach

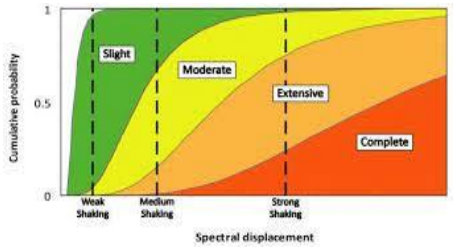


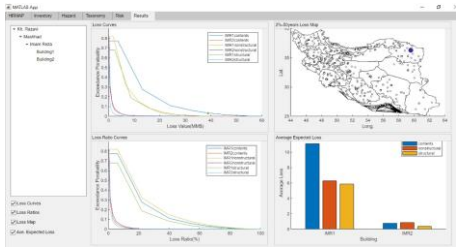


Inventory | **Hazard** | **Vulnerability** | **Loss and Risk**









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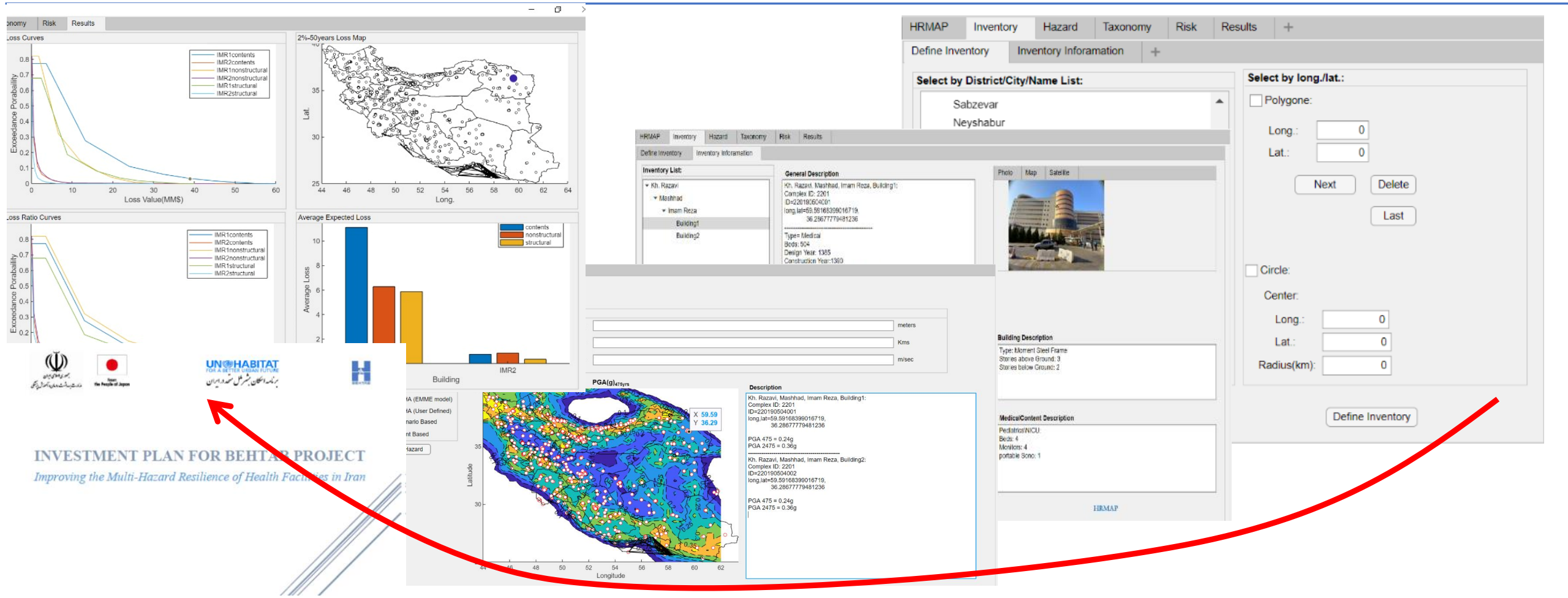
HRMAP-Analysis



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Training Courses and Workshops

Training No.	TITLE	DATE
1	**Basics of improving the resilience of hospitals and health facilities with a glance at Kermanshah earthquake**	September 2021
2	**Application of seismic isolators on improving the resilience of hospitals and health facilities**	November 2021
3	**Consideration of flood, fire, and other hazard in the planning and implementation of hospitals and health facilities**	December 2021
4	**Design and implementation of non-structural components in hospitals with regard to the seismic consideration**	February 2022
5	**Implementation technics of structural and non-structural components of hospital for site technicians**	April -May 2022
6	**Outputs of the studies of BEHTAB II- Part I: Vulnerability studies**	July 2022
7	**Outputs of the studies of BEHTAB II- Part II: Retrofitting Design studies**	August 2022

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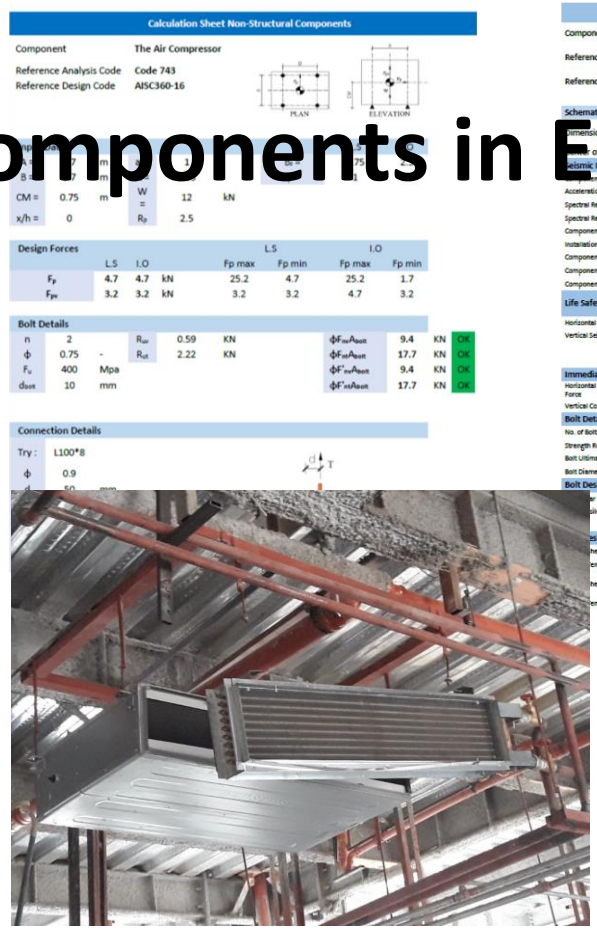
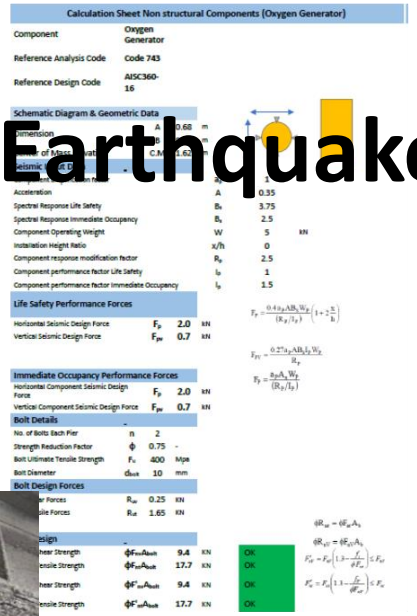
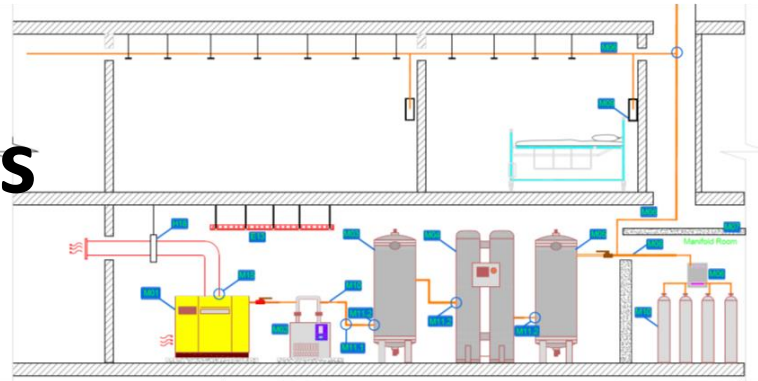
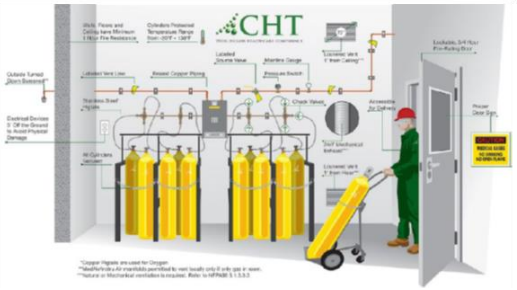
Part 2:

Nonstructural Components in Earthquakes









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Contents

- Introduction
- Structural Components vs. Hospital Non-structural components (HNCs)
- HNCs categorization for Functionality
- Experiences in previous earthquakes
- Consequent risk of damage to HNCs.

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Structural and Non-structural Elements

Structural Elements [FEMA-74]

The structural components of a building resist gravity, earthquake, wind, and other types of loads and typically include the following elements:

- columns, pillars
- trusses, girders, beams, joists, and purlins
- load-bearing walls that provide vertical support or lateral resistance
- diagonal elements such as braces
- floor and roof slabs, sheathing or decking
- foundation systems

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Structural and Non-structural Elements

Non-structural Elements [FEMA-74]

- The non-structural components of a building include all building parts and contents other than those previously described as structural.
- These components are generally specified by architects, mechanical engineers, electrical engineers, and interior designers.

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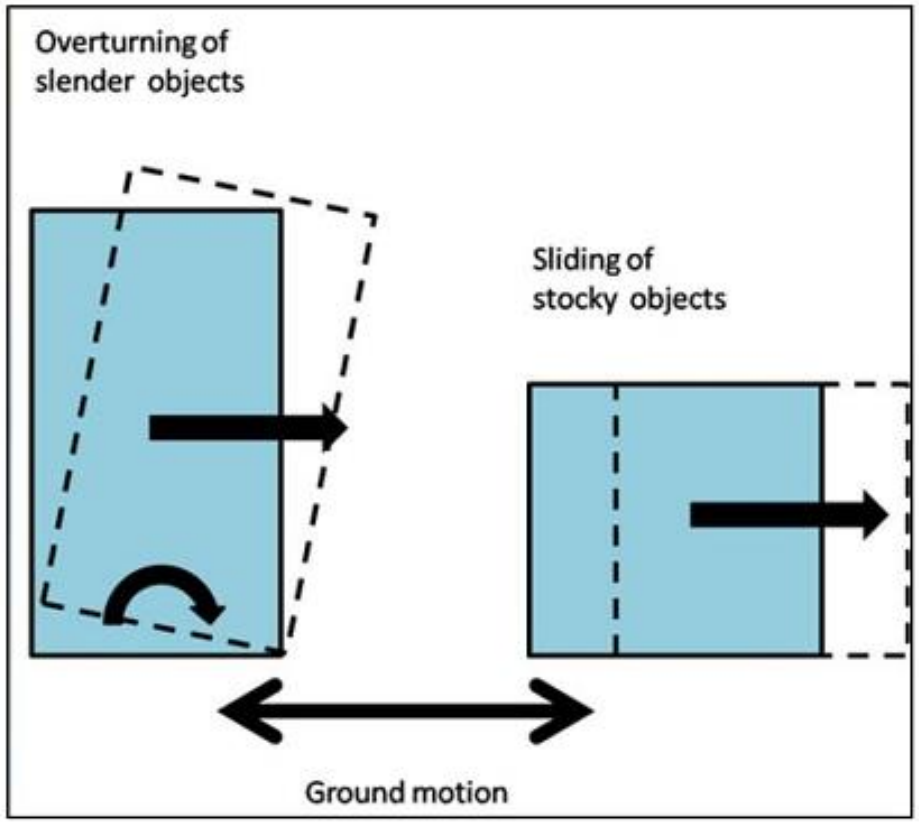
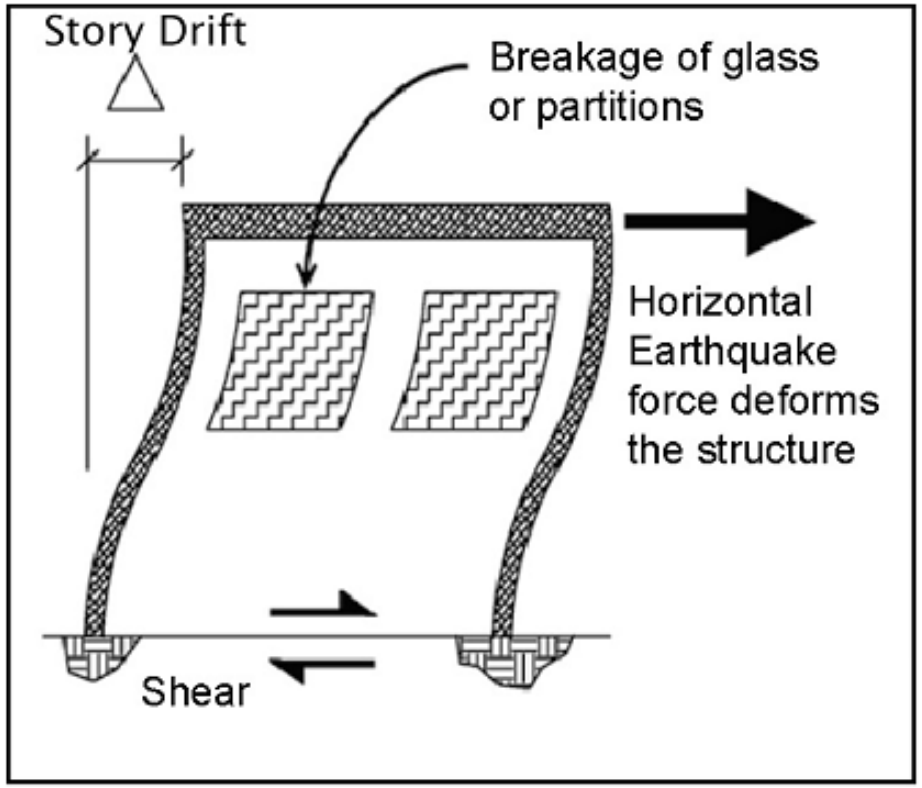
Seismic Behavior of Non-structural Elements





Inertial forces

Damage due to building deformation.

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Seismic Behavior of Non-structural Elements

Deformation sensitive

Acceleration sensitive

Damage Experiences

Broken piping in the new powerhouse for the Olive View Hospital, 1971 San Fernando earthquake (NISEE, 2016b).

Fractured sprinkler line and dislodged light fixture in the Olive View Medical Center, 1994 Northridge earthquake (NISEE, 2016d).

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Damage Experiences: Veneer

Adhered veneer damaged during the 2014 South Napa earthquake (FEMA, 2015a).

Veneer damaged during the 2017 Kermanshah earthquake Paveh Hospital (IIEES-2017).

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Damage Experiences: Veneer

Adhered veneer damaged during 2017 Kermanshah earthquake Tazeh Abad Health Center, (IIEES-2017)

Adhered veneer damaged during 2017 Kermanshah earthquake Tazeh Abad Hospital (IIEES-2017)

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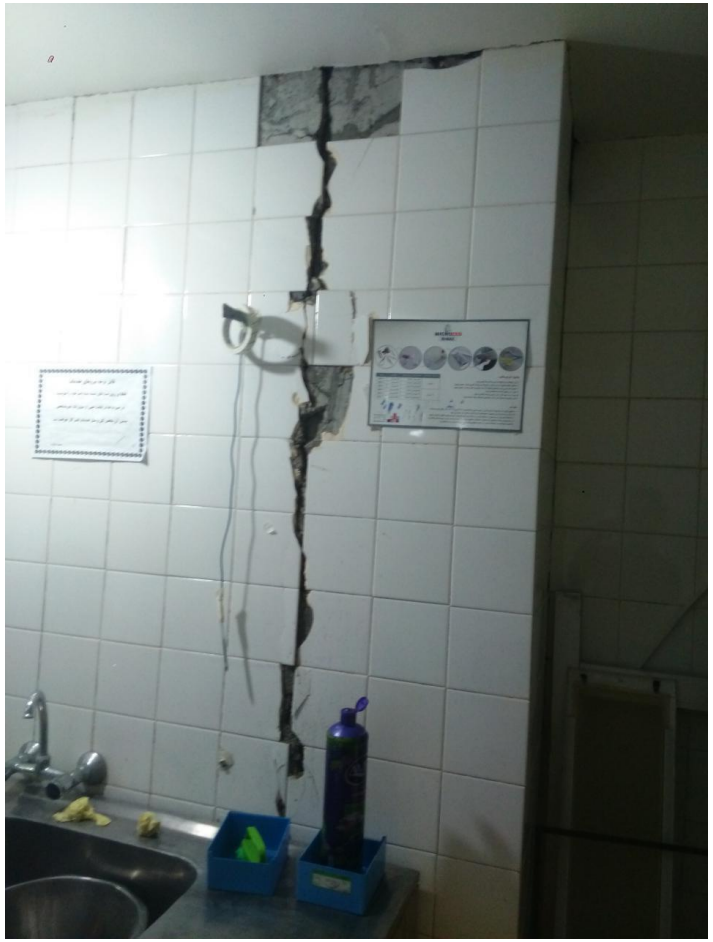
Damage Experiences: Interior and Exterior Walls



Damage to interior walls, 2017 Kermanshah earthquake Javanrood Hospital (IIEES-2017).

Damage to interior walls, 2017 Kermanshah earthquake Sarpol’e Zahab Hospital (IIEES-2017).

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Damage Experiences: Interior and Exterior Walls

Crack at the contact point of RC column and infill wall, Ache, Indonesia (2009)

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Damage Experiences: Suspended Ceilings

Failure of suspended ceilings, 2017 Kermanshah earthquake Sarpol’e Zahab Hospital (IIEES-2017).

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Damage Experiences

Swage breakage, 2017 Kermanshah earthquake Paveh Hospital (IIEES-2017).

Water pipe breakage, 2017 Kermanshah earthquake Paveh Hospital (IIEES-2017).

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Danage HVAC Equipment, 2017 Kermanshah earthquake Sarpol’e Zahab Hospital (IIEES-2017).

Damage to HVAC components, 2017 Kermanshah earthquake Sarpol’e Zahab Hospital (IIEES-2017).

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Damage Experiences

Damage to piping system, 2017 Kermanshah earthquake Sarpol’e Zahab Hospital (IIEES-2017).

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Damage Experiences

Damage to Water pumps, 2017 Kermanshah earthquake Ghasre Shirin Hospital (IIEES-2017).

Damage to piping system, 2017 Kermanshah earthquake Ghasre Shirin Hospital (IIEES-2017).

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Damage Experiences: Electric Systems

Damage to electricity channels, 2017 Kermanshah earthquake Ghasre Shirin Hospital (IIEES-2017)

Fire incident in electricity Cabinet, 2017 Kermanshah earthquake Ghasre Shirin Hospital (IIEES-2017).

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Damage experiences: Power Systems

Damage to Diesel Gen. Fuel Tank, 2009 Ache earthquake (2009).

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Damage Experiences: Medical equipment

Damage to medical equipment, Selaguri hospital,
Overturning and Damage to the X-ray equipment observed 2009 Ache earthquake (IIEES, 2009)

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Damage experiences: Contents

Damage to shelves in archive room, 2017 Kermanshah earthquake Gilan’e Gharb Hospital (IIEES-2017)

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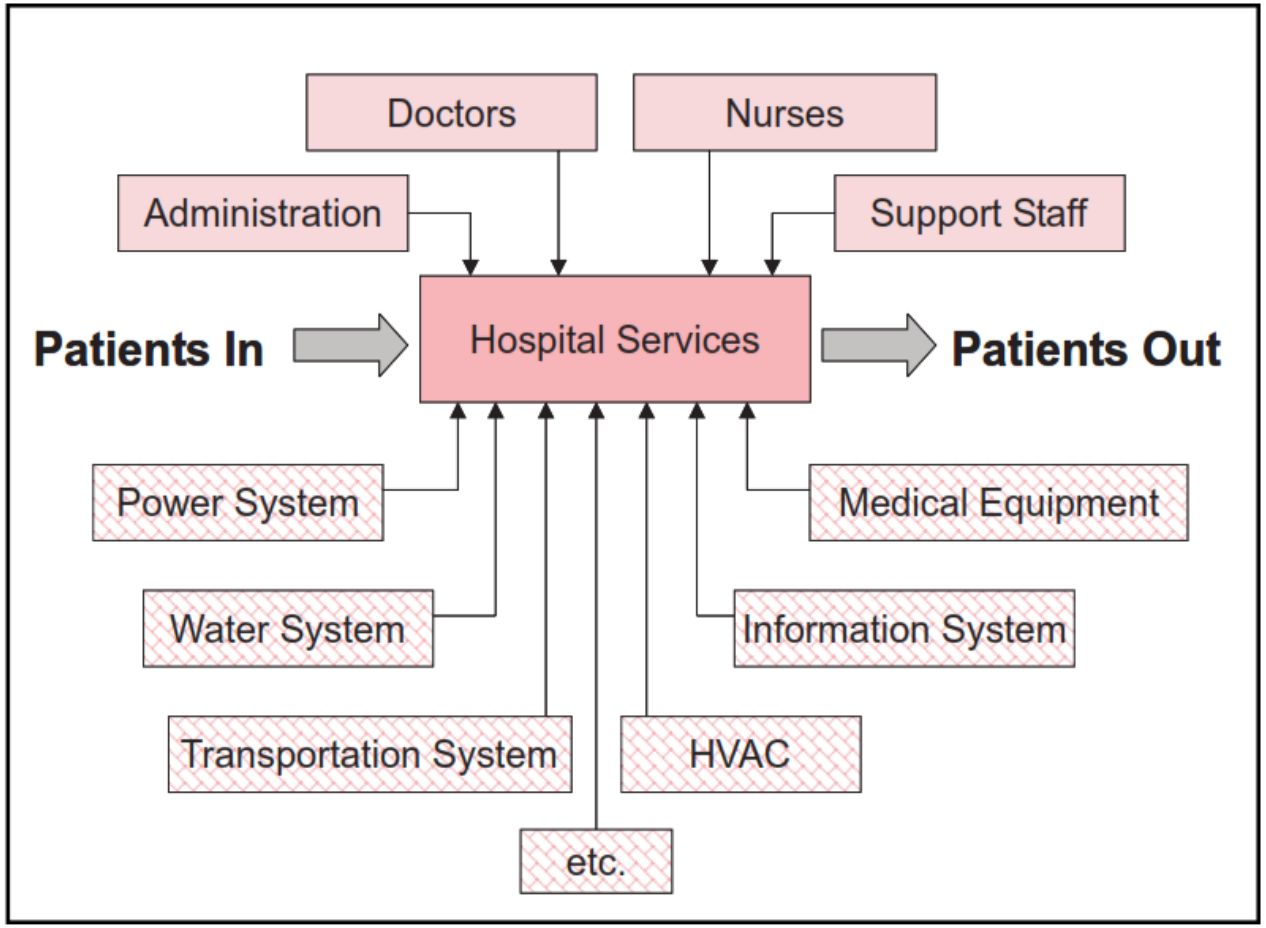
Patients flow in Hospital facilities as a system



Connectivity
Interdependency
Resilience

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Systems Contributing Functionality of Hospitals

- Structural Components
- Non-Structural Components
- Institutional Aspects
  - Lifeline Facilities
    - Medical Gas System
    - Fire System
    - Electricity System
    - Water Supply System
    - Communication System
    - Emergency Exit Systems
  - Medical Facilities
  - Architectural Elements

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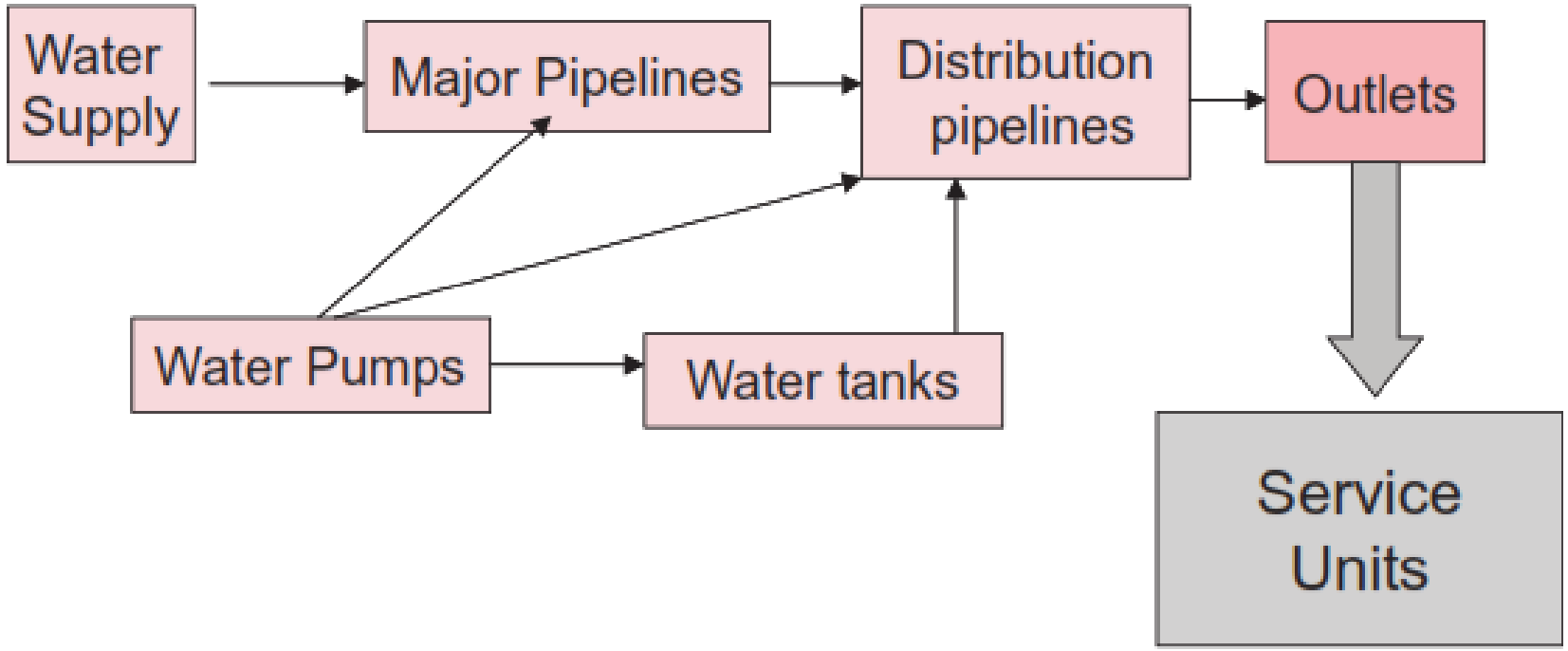
Flow diagram in Health facilities – Water System



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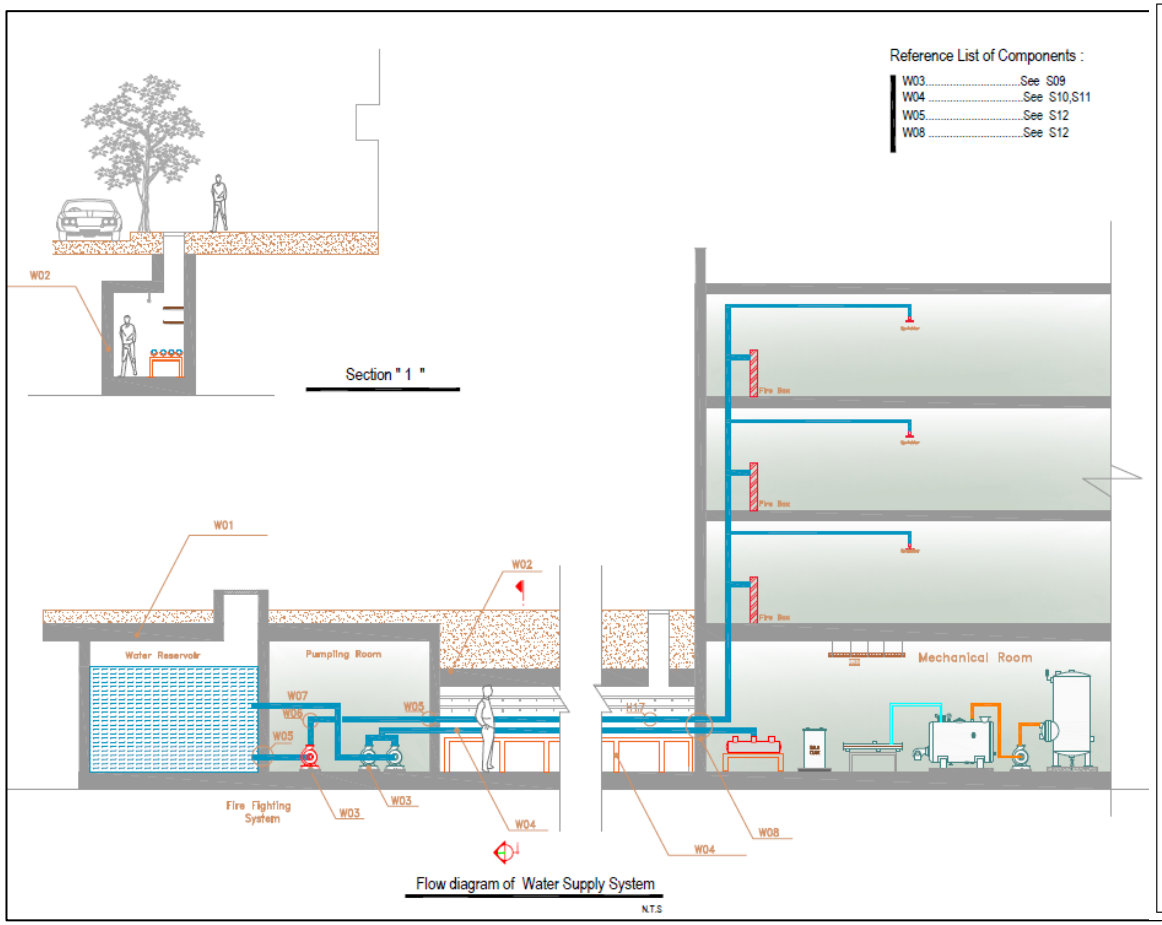
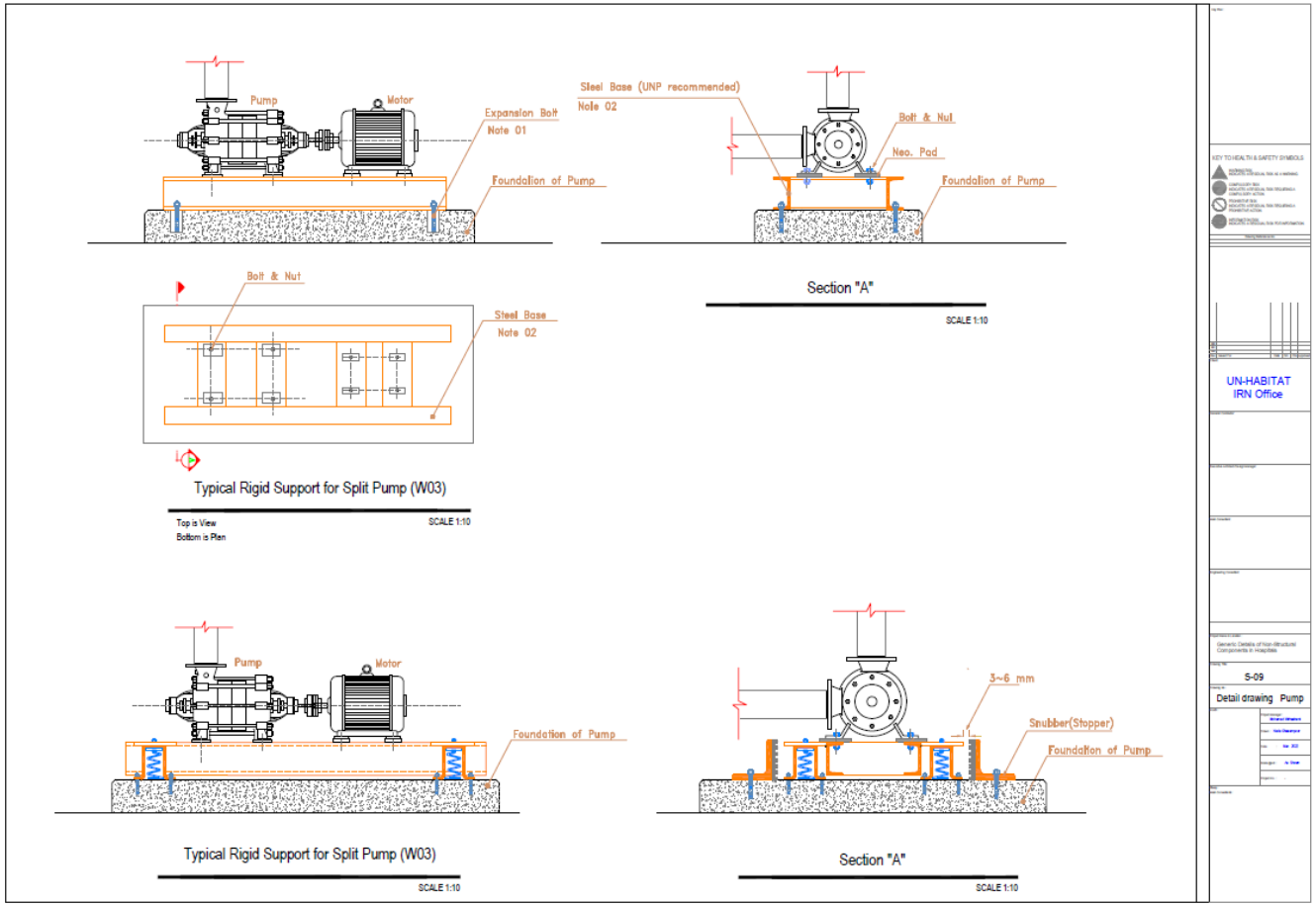
BEHTAB-II: A Hybrid System-Performance approach





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Need for an action plan for seismic risk management (Hazard and vulnerability identification and retrofit implementations)

Special approach to non-structural damage

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- Deepen the knowledge for design and assessment of HNCs
- Preparation of an Inventory of non-structural components
- Seismic vulnerability assessment (RVA-PEA)
- Provision of Retrofitting and resilient details for implementation in hospitals
- Regular Inspection programs
- Certification of critical mechanical, Electrical and medical equipment in hospitals

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Thank you for your attention

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