Global Facility for Disaster Risk Reduction

Global Program for Safer Schools

Mongolia Mission Report

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1 Executive Summary

Mongolia was identified by the World Bank (WB) as a country for Arup to provide technical support to the WB country task team to inform the development of a GPSS (Global Program for Safer Schools) TA program.

This study was conducted by Arup over a 7 week period and includes a hazard desk study, a review of documentation and a fact finding mission to Ulaanbaatar (UB) City in Mongolia, which encompassed rapid visual assessments of 12 school buildings and meetings with various key stakeholders.

UB City is undergoing rapid and uncontrolled urbanization, with the population having approximately doubled in the last 10 years to 1.3 million. Investment in maintenance of existing school buildings and construction of new has failed to keep pace with increasing demand. As a result there is a chronic shortfall of classrooms manifested by severe overcrowding. Furthermore, there is a new found focus on disaster risk reduction.

The critical hazard posing a risk to schools in UB City is seismic, with recent research identifying several nearby active faults that are capable of producing large earthquakes. Awareness of the hazard has been raised by the Japan International Cooperation Agency but is inhibited by the fact that there is no recent or historical experience of a significant earthquake.

Flooding does appear to pose a significant risk to schools at present whilst no evidence of past or potential future landslides or avalanches was gathered during the mission. Flooding and landslides/avalanches may pose an increased risk in the future unless they are considered in planning of new school infrastructure.

Existing school buildings are in poor repair as a result of a lack of maintenance, with 30% being over 40 years old. The oldest 75% have little or no seismic design consideration and so vulnerability of an aging building stock is a justified concern. Preliminary estimates based on the findings of this study are that 50% to 80% of school buildings are in need of retrofitting in order to address seismic vulnerabilities.

The collapse of the Soviet Union in 1991 and subsequent withdrawal of support to Mongolia prompted the collapse of the Mongolian economy and government institutions. The re-building of institutional capacity is a work in progress. The MoES is primarily responsible for identifying and providing new schools and maintenance of existing. They are assisted by various other government agencies. There are weaknesses in planning (site selection), procurement (lowest cost), design certification and construction monitoring (lacks capacity) and the assessment of existing buildings.

It is recommended that the WB invest in a Comprehensive School Infrastructure Program which addresses the deficit in classroom capacity whilst integrating school safety. It is recommended that Technical Assistance is provided to plan and design the program which will include a comprehensive vulnerability assessment of schools in the city, building upon existing work done by government agencies, the results of which are populated in a GIS database. This database will enable a thorough prioritization/risk assessment to be conducted which will in turn inform further Technical Assistance to produce guidance and tools to help build the capacity of those responsible for safer school infrastructure.

2 Introduction

Each year, natural disasters result in school buildings being destroyed or severely damaged leading to loss of life, injury and disruption to education. Global efforts to make schools more resilient have largely focused on improving awareness and preparedness so that teachers and children are better prepared and able to take appropriate action. Less attention has been paid to the physical performance of school buildings, which is the focus of a new initiative by the Global Facility for Disaster Risk Reduction (GFDRR) - the Global Program for Safer Schools (GPSS). This is being designed as a technical assistance (TA) program targeting countries where there is on-going or proposed investment in schools infrastructure.

Mongolia was identified by the World Bank (WB) as a country for Arup to provide technical support to the WB country task team to inform the development of a GPSS TA program.

The main aim of this study is to get a rich understanding of the vulnerability of school infrastructure and contributing factors of risk in order to identify entry points to embedding 'safer schools' in Mongolia.

The associated objectives are:

1. To understand the drivers of risk and range of hazards that may compromise the planning, design, construction and operation of school facilities.

2. To understand the number and the construction typology of existing schools in Ulaanbaatar (UB) City and those that will be constructed over the next decade.

3. To understand the institutional environment and regulatory framework within which school infrastructure is planned (including site selection), designed, constructed, operated, maintained, repaired and retrofitted and any discrepancies between the legislation and what is currently practiced in UB City.

4. To make recommendations to the WB country team where to prioritize GPSS's investment and future operations to increase the resilience of the school building stock.

3 Context

Mongolia is geographically isolated sharing its northern and southern borders with its two larger neighbors, Russia and China (Figure 1). Ulaanbaator (UB) City is located in the central Northeast of Mongolia, situated within the Tuul River Valley, with steep mountains to the South and gentler sloping mountains to the West, North and East. The majority of buildings in UB City are located on flat terraces bounding the Tuul River but recent growth of the city has resulted in development on the slopes to the North of the city, and in the tributaries of the Tuul River.

Figure 1 – Map of Mongolia

It is exposed both climatic and geophysical hazards. UB city is subject to extreme temperature fluctuations between summer (+30°C) and winter (-30°C). Up until recently the perceived major hazard affecting Mongolia was the severe winter weather, 'Zuds'[1], which have threatened and killed many of the livestock that the economy traditionally relied upon. Previous WB Disaster Risk Reduction projects have focused on the impact of 'Zuds' on livestock.

The population of UB City has approximately doubled in the last 10 years and is now 1.3 million. UB City comprises 46% of the population of Mongolia compared to 32% 10 years ago[2]. This is due to nomadic herders settling on the edge of the city in informal settlements known as 'Ger'[3] districts. Rapid and uncontrolled urbanization over the last ten years has shifted the focus of disaster risk reduction (DRR) from livestock to humans.

[1] A Mongolian term for a severe winter.
[2] http://databank.worldbank.org/data/views/reports/tableview.aspx and http://www.themongolist.com/blog/society/71-ulaanbaatar-a-city-built-for-400,000.html
[3] A Mongolian term for a traditional wooden framed, felt covered shelter favored by nomads.

The primary natural hazard affecting school safety in UB City is Earthquakes. UB City has experienced no significant earthquakes in recent or historical time. Recent geological research[4] in the area conducted by Japanese International Cooperation Agency (JICA) has identified several active faults in the vicinity of the city, capable of producing large earthquakes.

According to the Ministry of Education and Science (MoES) there are over 700 schools in UB City of which 299 are government schools. Due to the increasing population many classrooms are overcrowded and multiple ‘shifts[5]’ are the norm in an attempt to alleviate pressure. Investment in school infrastructure, in terms of new buildings and maintenance of old, has failed to keep pace with increased demand as a result of a lack of investment dating back to the collapse of the Soviet Union (Figure 2). In 1991 school construction came to a halt, resulting in a decade where few schools were constructed. Donors (JICA, World Bank, and World Vision) stepped in to fund new construction but this assistance appears to now be tailing off as the Mongolian economy strengthens.

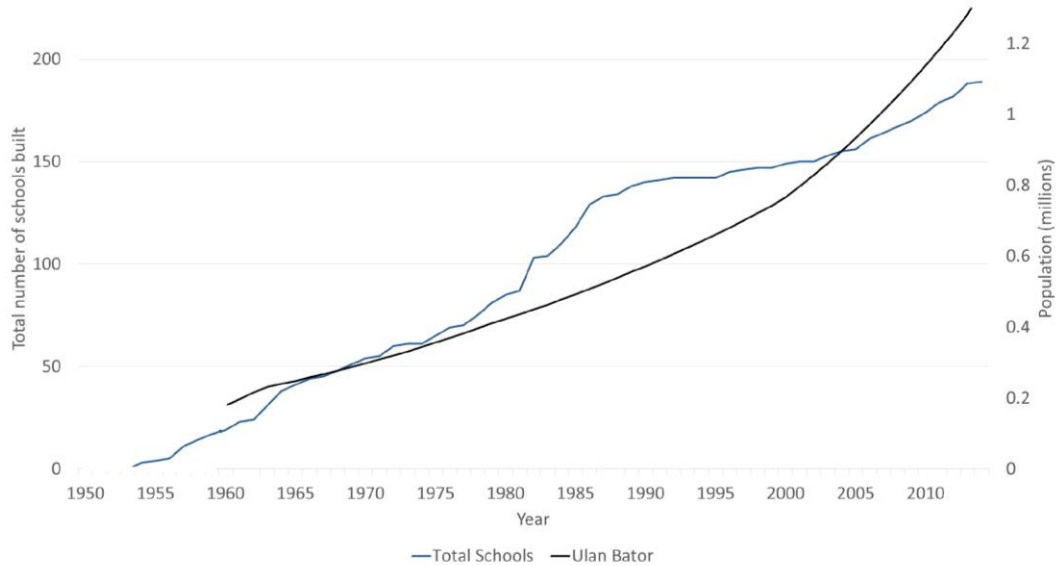

Figure 2 – Cumulative number of schools built in UB City and population growth. (List of schools provided by the World Bank Task Team and population data from the World Bank website)

[4] The Project for Strengthening the Capacity of Seismic Disaster Risk Management in Ulaanbaatar City - Final Report, 2013
[5] The school day is split into 2 or 3, such that a child attends for ½ or 1/3 of the day.

4 Methodology

This study was conducted by Arup International Development (Arup) over a 7 week period. During this study the following activities were undertaken;

- A **Hazard Desk Study** of UB City. This included the review and commentary on existing data to identify the frequency and intensity of hazards. (Refer to Appendix A for seismic and flood hazard summary notes);
- A **Documentation Register** of documents obtained before and during the mission to UB City (Refer to Appendix B for document register);
- A 10 day **fact finding mission** to UB City (Refer to **Error! Reference source not found.**) undertaken from 13-21 November 2014 which included;
    - **Meetings with key stakeholders** in UB City (Refer to Appendix **Error! Reference source not found.** for a list of meetings)
    - **School Visits.** Rapid Visual Assessments (RVA) were undertaken on a sample of schools. (Refer to Appendix C1 for a list of schools visited)

The Rapid Visual Assessment (RVA) (Refer to Appendix D) was based upon the methodology outlined in the Arup Report 'Assessment and Delivery of Safe Schools[6], which references a comprehensive range of sources and pre-existing assessment tools such as FEMA guidelines and the AKDN Rapid Visual Assessment Screening Method. It also builds upon work conducted by Arup in assessing over 400 ready-made garment factories in Bangladesh following the collapse of Rana Plaza in 2013[7].

The methodology was further refined into a country specific tool prior to the mission based upon the hazard desk study. An assessment form was created in Fulcrum[8], a web based data collection app (Refer to Appendix D2 for a full list of questions). It comprised 3 main sections, namely:

1. User Interview
2. Site Exposure Assessment
3. Building Vulnerability Assessment

[6] Assessment and Delivery of Safe Schools, Arup December 2013 (developed on behalf of GFDRR to inform the final design of GPSS)
[7] http://en.wikipedia.org/wiki/2013_Savar_building_collapse
[8] http://fulcrumapp.com/

5 Key findings

5.1 Hazards

The critical hazard posing a risk to school safety in UB City is seismic. Flooding and landslides may pose an increased risk in the future unless they are considered in planning of new school infrastructure.

Seismic

There have been no significant recent or known historical seismic events in UB City. Small earthquakes did occur in 1998 and 2006, with minor damage to old buildings being reported, however just one of the schools visited reported having ever felt a tremor.

Three active faults have recently been identified in the region immediately surrounding UB City[9]. The resulting seismic hazard was investigated as part of a JICA study[10] in 2013 and is classified as MSK[11] level 7. The Arup seismic hazard desk study (Refer to Appendix A1) translates this into a peak ground acceleration (PGA) of up to 0.35g. The United States Geological Survey (USGS) describes this as “Severe” shaking resulting in "Slight damage in specially designed structures; considerable damage in ordinary, substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned".

As well as examining the seismic hazard, the JICA report investigates liquefaction, landslides, flooding, building and infrastructure risk evaluation and gives guidance on earthquake disaster prevention planning and disaster education. It makes a series of recommendations including a review of Mongolian seismic design codes and standards. It is unclear whether this recommendation has been taken forward since the report was issued.

Seismic risk maps are reportedly available for UB City but were not forthcoming during the field mission. They do not appear in the current norms (building code) which is a direct translation of the Russian Code. Different stakeholders reported the Mongolian seismic hazard level differently, with the Department of Education (DoE), Mongolian Association of Civil Engineers (MACE), Construction Development Centre (CDC) Validation division and CDC Norm and Normative department stating the level to be MSK7 to 9, 7 to 8, 6 to 8 and 7 to 9 respectively. In order for seismic vulnerability of schools in UB City to be addressed it is important that the key stakeholders are aware of the true hazard level and that it is included in the regulatory framework.

Awareness of the seismic hazard is generally good predominantly due to advocacy undertaken by JICA. It is recognized as an important issue by the Government at national and city level. In 2010 a national program was initiated

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[9] The Project for Strengthening the Capacity of Seismic Disaster Risk Management in Ulaanbaatar City - Final Report. JICA (2013)

[10] The Project for Strengthening the Capacity of Seismic Disaster Risk Management in Ulaanbaatar City - Final Report JICA (2013)

[11] Medvedev–Sponheuer–Karnik is a seismic intensity scale somewhat similar to the Modified Mercalli (MM) scale used in the United States

by the Ministry of Roads and Construction (MoRC) for the Prevention and Reduction of Earthquake Disaster Risk. In 2011 NEMA (National Emergency Management Agency) took over the program as the MoRC lacked the funds to implement it, and have since played a major role in undertaking training and developing methodology for earthquake risk reduction. Moreover, the education policy appears to respond in part to both Pillar 2, School Disaster Management and Pillar 3, Risk Reduction and Resilience Education of the Comprehensive School Safety Framework[12] as earthquake hazard awareness is on the school curriculum, whilst every school that was visited had an evacuation plan.

Where seismic design appears to have been considered in the design of buildings there seems to be a general misunderstanding of how the buildings will perform in a seismic event. The life safety[13] nature of building code design will make return to operation more challenging than was suggested in interviews with NEMA. There does not appear to be a national or city level plan for how to return pupils to a learning environment in the aftermath of a seismic event. Given the vulnerabilities of the aging building stock this lack of preparedness will make recovery much more difficult.

Flooding

Flooding has been identified as a potential hazard to school and kindergarten buildings in UB City. The Arup flood hazard desk study (Refer to Appendix A2) highlights that the city has experienced floods in 1966, 1982, 2003 and 2009. In 2009 24 people are known to have died and hundreds made homeless. Although areas prone to flooding were historically avoided as the city developed, increasing land pressure means that flood risk in the city is increasing. This is a function of the city's growing population, presence of numerous watercourses and lack of formal planning. There are two main flooding mechanisms in UB City:

1. Flooding from primary river systems caused by rapid snowmelt in spring
2. Flash flooding from minor and ephemeral watercourses following heavy rain

These create different challenges in terms of the impacts on the built environment and the ease of forecasting and providing early warning. The flash flooding risk is as much about water run off as it is about flow along ephemeral watercourses. It is important that the site location is considered in terms of its proximity to local water bodies as well as the physical planning of the site which includes flood mitigation measures, such as drainage, and building design, such as elevating the ground floor level above the flood level.

Of the schools visited five (56%) could remember the immediate area being subject to a flood, two of which occurred in the last 20 years with one occurring in 2009. Of the five schools two experienced disruption. Kindergarten #12 had its raised timber floor replaced whilst the basement gym/hall of School #61 had water bailed out of it by bucket. Man-made surge channels were seen in several

[12] www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/Comprehensive_school_safety.pdf
[13] Life safety design assumes that buildings will suffer some damage and may require significant repair or even demolition.

areas visited and were cited by Kindergarten #59 as having provided protection against flooding.

UB City NEMA report that flooding is a risk primarily in Bayanzurkh and Songino Khairkhan Districts and that there are flood hazard maps held by the Land Administration Office, but that they aren't always enforced. The DoE (Department of Education) reported that flooding is not considered during planning/site selection.

A WB funded project[14] to prepare an investment road map on flood risk management is currently underway, with a flood hazard map for UB City due to be completed shortly. This will include 1 in 50,100,500 and 1000 year floods from five different sources of flooding (each fits into one of the 2 broader categories listed above). The Asia Foundation has compiled community based historical flood maps, with a draft version available at www.manaikhoroo.mn. At time of writing, this included colored blocks on a map without supporting data to describe the hazard or risk. They are also developing a website concerning flood risk management is also currently under construction.

Landslides/Avalanches

Landslides are typically triggered as a result of heavy rain/ flooding or earthquakes. The JICA 2013[15] report determined that the steep slopes surrounding the city could be susceptible to landslides. No evidence of past or potential future landslides or avalanches was gathered during the mission. As rapid urbanization continues, development is encroaching onto hillsides. The risk of landslides and avalanches will increase if development remains unplanned and unchecked.

Opportunities

There is an opportunity to build on and interpret the work that JICA have undertaken and to make this information usable, for example, to develop up to date hazard and risk maps that can be used for the planning and design of buildings such as schools and kindergartens and incorporated in the Mongolian Norms.

There is an opportunity, once completed, that the flood hazards maps being produced as part of WB funded project can be integrated in to the planning regulations to inform site selection processes to determine the planning and design of future development including school infrastructure.

[14] Improving Disaster Risk Management in Mongolia project
[15] The Project for Strengthening the Capacity of Seismic Disaster Risk Management in Ulaanbaatar City - Final Report JICA (2013)

5.2 Existing School Infrastructure

Currently there are 119 kindergartens and 180 (primary/secondary) schools in UB City[16]. The collapse of the Soviet Union in the early 1990s resulted in a lack of investment in school infrastructure. This, partnered with rapid urbanization, has resulted in a chronic shortfall of classrooms in UB City with the majority of schools over capacity and operating at least 3 shifts a day to try and meet the demand. The Ministry of Education and Science (MoES) has identified a need for a further 300[17] new school buildings, representing a 60% increase in school building stock, to meet the current deficit. This assumes that many schools will still operate two shifts per day. Overlaid on this many of the existing school and kindergarten buildings are old and in poor condition due to lack of maintenance.

After 1990 the weakened government spending was supplemented by donors, with JICA, World Vision and the WB all funding new buildings, often as additional buildings on existing school sites. Having constructed 45 schools in UB City since 1999 JICA have now withdrawn their aid as a result of economic growth. The last of 17 WB funded Canadian Timber Technology schools are due to open in December 2014. The original intention was to construct 34 schools but the program was curtailed due to significant construction delays and financing issues. Some took up to 2 years to construct, with the resulting inflation reducing what was affordable

Currently there are no known on-going donor funded construction programs in UB City. An Asian Development Bank school construction loan offer for $25million (USD) is currently under consideration by the Government. The MoES now has a national budget of USD100 million, which is 28% of what the 2011 MoES Policy Document predicted would be needed for school construction in UB City alone (USD 352.5million).

There is an additional problem that the Government does not own the land necessary to construct new schools and the DoE cites soaring land prices as a key concern that is driving up the cost of new construction. Existing schools are therefore being extended (vertically and horizontally) in an attempt to alleviate pressure (See Appendix G, Figure G1.4),

67% of the schools that were visited were planning significant repairs, modifications or extensions, however, school principals were generally not hopeful of receiving the funding they required citing insufficient funding for the MoES.

Opportunity

There is an opportunity to develop a strategic approach to improving the vulnerability of existing school buildings that incorporates seismic considerations in retrofitting and building modifications.

[16] UB City Nema – Introduction of Schools and Kindergartens to Make Assessment
[17] MoES 2011 Policy Document – Needs for new kindergartens, schools, dormitories and gyms and options to meet them

5.3 Construction Typologies

Twelve school buildings (Refer to Appendix C1) were surveyed using the RVA form developed by Arup (Refer to Appendix D2). The results of survey can be found in Appendix **Error! Reference source not found.**. From these surveys eight construction typologies were identified (Refer to Appendix D2 and **Error! Reference source not found.**). These were further reduced to four categories for the purpose of describing their vulnerability. Refer to Table 1 for a list of the construction typologies and categories. The vulnerability categories are broadly defined by chronology. The reasons for this are explained within the following text whilst a comprehensive list of key dates (Appendix F1) and further analysis of how typology and vulnerability have evolved over time is given in Appendix F2.

Table 1- Construction Typology and Categories

Construction Typology	Categories	
1. Pre 1950 Unreinforced Masonry	Pre 1975	Soviet Model Design with no seismic detailing
2. Pre 1950 Timber		
3. Pre 1975 Unreinforced Masonry		
4. Pre 1990 Reinforced Masonry	1975 – 1990	Soviet Model Design with some seismic detailing
5. Donor Funded Reinforced Masonry	1990 – 2014	Varied Designs
6. Donor Funded Reinforced Concrete Frame		
7. Donor Funded Timber Frame		
8. MoE Model School	2014 -	New Model Designs

General Vulnerabilities

Generally school buildings appear to be engineered, with the majority of schools visited (75%) able to provide engineering drawings during the visits. Schools are typically constructed of loadbearing brick masonry walls with a mixture of pitched and flat roofs, founded on strip footings. Fundamental best practice principles of seismic design such as plan and vertical regularity are typically not well adhered to.

Pre-1990 schools were constructed to 'model school'[18] designs of Soviet origin. Schools built up until 1975 (approx. 30% of UB City schools) are thought to have minimal or no seismic consideration and are most vulnerable. Schools built between the 1975 and 1990 (approx. 45% of schools) generally have some limited seismic detailing, and are slightly less vulnerable. Schools built after 1990 up to this day (approx. 25% of schools) are built to varied designs, some of which are likely to be vulnerable, including current MoES 'model school' designs.

[18] Model School refers to a standard design which is built repeatedly. Soviet model and current MoES model designs vary by pupil capacity as well as by Kindergarten or Primary/ Secondary.

The following sections describe in more detail the vulnerabilities of the 4 categories identified above and summarized in Table 2. For photos illustrating the key vulnerabilities refer to Appendix G. G

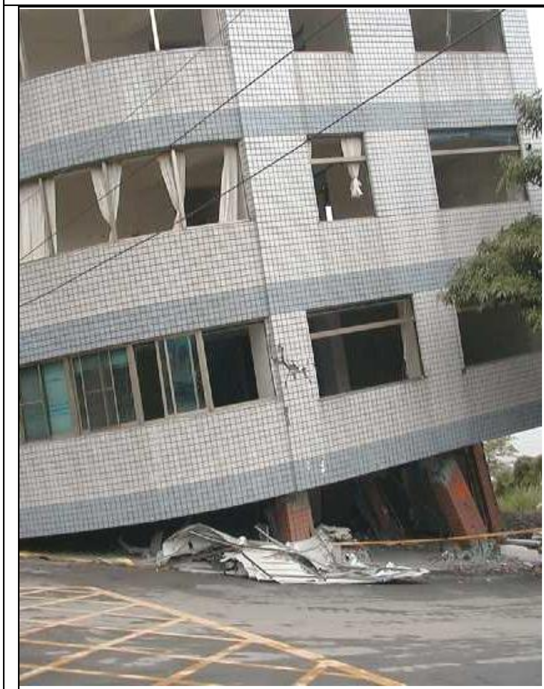
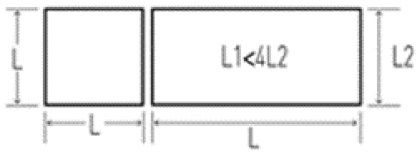
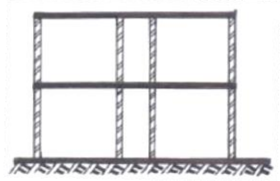
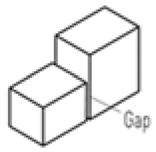
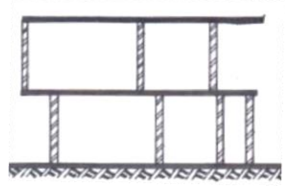
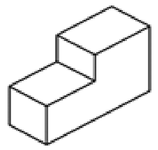
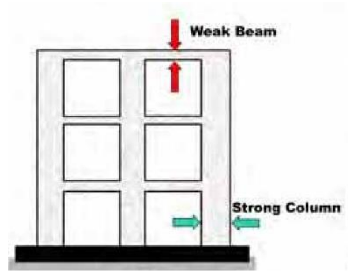
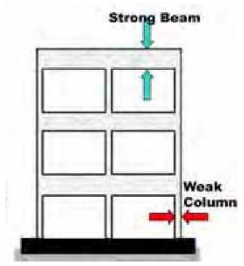
	
Collapse of ground level caused by Vertical irregularity	Damage to primary structure caused by interaction between non-structural masonry and RC frame
	
Torsional damage caused by plan irregularity, specifically l>4b	Damage resulting from pounding

Table 2 – Summary of vulnerabilities associated with each construction category

		Category			
		Pre 1975	**1975 - 1990**	**1990 - 2014**	**2014 -**
Key vulnerabilities	**Design**	No diaphragm. Vertical irregularity*. Plan irregularity*. Pounding risk* Foundation movement.	No diaphragm. Vertical irregularity*. Plan irregularity*. Pounding risk *	No diaphragm. Plan irregularity*. Interaction between RC frame and non-structural masonry*. Pounding risk*	Interaction between RC frame and non-structural masonry*.
	Material Quality	Masonry is low strength.	Material quality unknown.	Material quality typically higher where donor funded.	Evidence of material certificates on site.
	Quality of workmanship	Poor masonry workmanship (unknown internal bonding).	Poor masonry workmanship (unknown internal bonding).	Construction supervision capacity reduced after 1990. Donor funded schools appear to have good quality of workmanship.	Evidence of poor concrete workmanship on site visited
	Deterioration (lack of maintenance)	Missing/damaged mortar and damaged bricks. Leaking roofs, water pipes and inadequate rain water management	Missing/damaged mortar and damaged bricks. Leaking roofs, water pipes and inadequate rain water management	Minimal	Unknown
		Vulnerable	**Less Vulnerable**	**Some Vulnerabilities**	**Some Vulnerabilities**

*Refer to Table 3for definitions and examples of seismic damage resulting from these characteristics

Table 3 Description of Seismic Design Considerations

Seismic Design Consideration	Description			Damage
Building Plan Layout	The plan shape of the Building should be square / rectangular with symmetrical arrangement of walls to avoid twisting (See Appendix E1.6) Buildings should be separated into rectangular shapes with a sufficient gap between structures to prevent **pounding** during an earthquake. (See Appendix E1.3)			 Torsional damage caused by **plan irregularity**, specifically l>4b  Damage resulting from **pounding**
Vertical Shape of Building	Walls and columns should be the same size and continue from roof level to foundation level in a straight line. Cantilevers should also be avoided. (See Appendix G – Figure G6.2) The elevation of building should be regular. Different parts of the building that are at different heights should be separate with a sufficient gap between the structures.	 	 	 Collapse of ground level caused by **Vertical irregularity**
Reinforced Concrete Beam / Column geometry	Strong beam/weak column implies that in the event of an earthquake the column would fail before the beam. Typically the intention is to focus plastic deformation within beams, such that the critical column elements retain their ability to withstand vertical loading and prevent collapse.			

Pre 1975 – Soviet Model Design with no seismic design

Soviet model schools are typically arranged on plan in ‘C’ or ‘E’ shapes; with some kindergartens consisting of approximately square (regular) plan arrangements. ‘C’ or ‘E’ shaped plans consist of independent rectangular brick structures that abut each other to form the ‘C’ or ‘E’. The joint between the structures is referred to as an expansion joint. It has not been designed for seismic movement and presents a pounding risk (See Table 3) that could cause localized damage. 60% of all the schools visited were at risk of pounding. This risk is reduced somewhat where the floor levels of the two structures are aligned. Increased vulnerabilities exist if double height spaces (such as gyms) are built immediately alongside structures with typical floor to floor heights.

External walls are brick masonry (approx. 600mm thick). Kindergarten #59 was the only school visited to provide material test data. The results indicated that the bricks had a low compressive strength of $2N/mm^2$, a factor which will contribute to vulnerability. Safe buildings require good quality materials with seismic codes typically requiring a minimum of $5N/mm^2$ for masonry brick compressive strength.

Internal wall layouts tend to be continuous vertically where classrooms are stacked above each other but can vary between floors for other room types generating vertical irregularities (See Table 3) and increased seismic vulnerability. Entrance halls are often open spaces that involve a number of walls above being discontinued. It is not uncommon for walls to be moved in school buildings, in order to re-purpose/rearrange space that is under pressure from overcrowding (See Appendix G, Figure G1.2).

Older buildings have timber floors (School#1, 1940 and Kindergarten #59, 1963 See Appendix E), whilst all others are pre-cast reinforced concrete hollow core planks with no topping. A reinforced topping would act to tie the planks to each other and to the supports (walls/beams), in effect tie-ing the building together at each floor level creating a diaphragm which is able to transfer lateral forces to the stability structure. The absence of a toping poses a local and a global behavior risk to the building. These buildings lack a floor diaphragm, increasing the overall stability of the structure. Furthermore, the planks are not effectively tied to the wall structure so in a seismic event the floor is of risk of collapse. Most seismic codes would not allow this form of construction.

Where it is exposed masonry workmanship is generally poor. Bond patterns are sometimes poorly detailed this is possibly decorative (See Appendix G Figure G2.1), coursing can be uneven and mortar is poorly pointed. Mortar coursing has often deteriorated following lack of maintenance (See Appendix Figure G3.1). In 2 schools large cracks in walls were witnessed consistent with foundation movement (See Appendix G Figure G3.2), possibly due to frost heave or subsequent settlement.

1975 – 1990 – Soviet Model Design with some seismic design

Construction typology evolved slightly after 1975. Timber floor structures were no longer used and precast concrete planks without topping remained the typical floor construction (See Figure E1.4). Seismic design was now considered, due to the introduction of the seismic Russian Code (Appendix F2), with the front cover of the drawings for one soviet model school stating that it was designed for MSK level 7. Some seismic detailing is evident on the drawings as a result, notably the inclusion of horizontal reinforcement in walls and inclusion of reinforced concrete (RC) ring beams at floor and roof level. Openings for windows and doors are supported by separate lintels. The ring beams typically follow the tops of the walls on plan and should provide additional tie-ing, however a topping (diaphragm) to the pre-cast floors remain absent.

These schools exhibited similar signs of deterioration to the first group, although generally less severe.

1990 – 2014 - Varied Designs

Most modern school designs, included JICA funded schools tend towards a reinforced concrete (RC) moment frame with what appears to be non-structural masonry walls. Precast planks are still in use without a topping and were seen on the drawings of both the JICA funded schools (School#58 and #61) which were visited.

RC moment frames for seismic design require complex reinforcement detailing which can be difficult to build to labor unfamiliar with the details. The JICA schools were constructed by Japanese contractors who would be familiar with this construction typology but this process does not contribute to building capacity of the local construction industry.

JICA schools tend to be rectangular 3 story buildings, but both JICA schools visited exceed an international best practice seismic requirement that limits the length of a structure on plan to 4 times its breadth (See Table 3). One of the JICA funded schools was observed to have strong beam weak column geometry. The Japanese have a good understanding of seismic design and these schools were designed by international consultants who would follow the Japanese Code whilst respecting Mongolian Codes. Therefore a more detailed engineering assessment would need to be undertaken to understand the vulnerability of these designs.

World Bank funded schools/ kindergartens are regular on plan and in elevation. They utilize Canadian Timber Technology (Kindergarten #59). This consists of an insulated timber clad timber frame. The light weight nature of the construction type and quality of workmanship witnessed means it has low vulnerability in earthquakes.

2014 - Onwards - Model School Design

The MoES has developed model school designs for kindergarten and schools (of varying pupil capacities). From 2014 all government funded schools that are constructed in UB City will be a model school design. The MoES were able to provide artists impressions of the model designs but were unable to share detailed engineering drawings.

A model kindergarten under construction was visited at Kindergarten #26. The structure consists of an RC moment frame with a cast in place RC floor slab. A cast in place floor slab means that the building has a diaphragm at each floor level and so will be well tied together. This will improve the seismic resilience of this design.

The local contractor was able to share engineering drawings illustrating seismic detailing for the reinforced concrete moment frame (See **Error! Reference source not found.** for an example of seismic detailing). It was not clear whether these details that been followed in the construction. No drawings were available for how the masonry brick walls have been designed and detailed. Non-structural masonry must be restrained such that it does not pose a local falling hazard whilst being isolated from the main structure such that it does not compromise its behavior. This interface between the structural RC frame and non-structural masonry is commonly overlooked in many parts of the world with potential deadly consequences.

Extensions

Schools buildings in UB city are currently limited to 3 stories. In Khan-Uul District three two-story schools were seen with an additional story (increasing to three stories) (See Appendix E1.4 - School #26). The DoE reports that its “resident technical expert” has preliminary identified additional schools suited to vertical extension although it is not clear what methodology was used to make these recommendations. NEMA and MACE both stated concerns over the safety of this practice but lack the capacity to address it.

Where buildings are extended vertically this increases their overall mass and their center of gravity which in turn increases the load that the building must resist in an earthquake. For example, if a 2 story masonry building has another masonry story added to it the seismic loads will have increased by approximately 30%. In the case that the lateral system has not been designed to resist this larger load, or if it has not been strengthened, the resulting risk to the building is high.

Where new buildings are constructed on a school site they are generally built immediately adjoining existing buildings with no consideration to seismic movement (See Appendix G, Figure G1.3), generating a potential pounding risk.

Where the floor levels of the new and existing buildings are the same this risk is small. Where the floor levels vary or if there are double height spaces (See Appendix G, Figure G1.1), there is the risk that one building could cause significant localized damage by colliding with its neighbor during an earthquake.

Opportunity

Through the MoES model designs there is an opportunity to ensure that every new school building that is built in UB City is a safe building and produce good quality design documentation that clearly communicates what needs to be built to facilitate construction.

5.4 Institutional Environment and Regulatory Framework

Responsibilities

The collapse of the Soviet Union in 1991 and subsequent withdrawal of support to Mongolia prompted the collapse of the Mongolian economy and government institutions. Re-building of institutional capacity is a work in progress.

The MoES has overall responsibility for new and existing school infrastructure and are assisted by various government agencies throughout the implementation process as illustrated in the table below.
Figure 3 shows their relationship to each other.

Stage	Task	Body Responsible
Planning	Needs assessment	Department of Education (UB City)
	Site selection	Department of Education (UB City)
		General Urban Planning department (UB City)
Design	Brief/ Feasibility	Department of Education (UB City)
	Procurement	City Investment Department - under USD 265k MoF - over USD 265k
	Delivery	Soviet models - pre 1990 Private Sector - after 1990
	Approval/ Construction certificate	Construction Development Centre Validation Commission NEMA - approves for fire
	Final Issue of Certificate	Ministry of Construction and Urban Development – 16+ Stories Local Government Land Administration – 2-16 stories Designer – Single story
Construction	Procurement	City Investment Department - under USD265k Ministry of Finance - over USD265k
	Supervision	Construction Development Centre Building Clients Division
	Occupancy certificate	National review commission - review compliance before handover takes place
Operation and Maintenance	Ownership	Ministry of Education and Science
	Assessment	National Emergency Management Agency - have 3000 risk assessments to undertake, yet to start.
		Construction Development Centre
		Special Inspection Agency
	Routine maintenance (e.g. painting, plastering)	Ministry of Education and Science
	Significant repairs (e.g. roof etc)	Ministry of Education and Science

Table 4 –Responsibility of government agencies throughout the implementation process

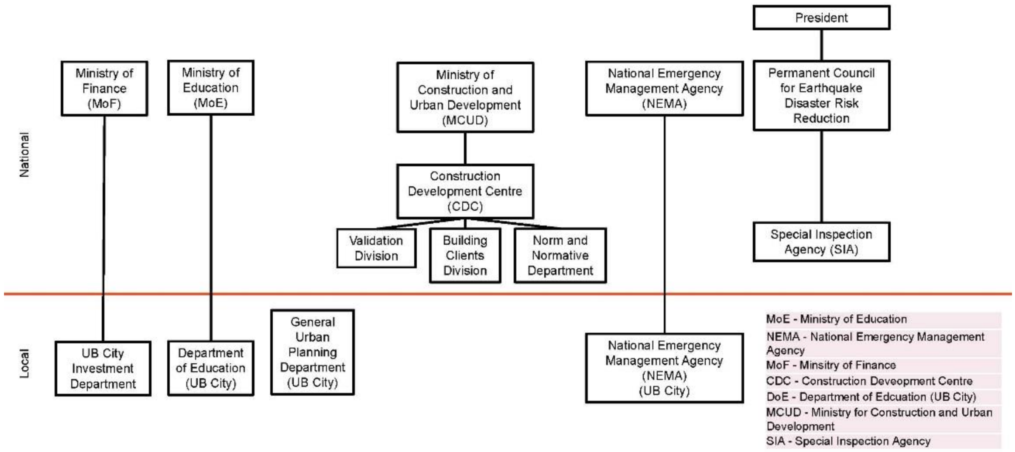


Figure 3 Diagram showing the relationship between the different government bodies

There are weaknesses in planning (site selection), procurement (lowest cost), design certification and construction monitoring (lacks capacity) and the assessment of existing buildings. These are explained in more detail below.

Planning

Site selection for new school buildings appear to be based on a needs assessment undertaken by the DoE by identifying areas within the city where there is an increasing demand for school classrooms. This also includes districts where schools don't currently exist that have recently developed[19]. Unplanned urbanization has meant land is in short supply and in some cases private developments are illegally encroaching on existing school properties.

There seems to be little, if any, consideration of natural hazards in determining where schools are located, for example, flooding and or landslides, and how those hazards play out locally at a site level. This stage is critical and often overlooked. The focus of this stage is to reduce exposure in terms of where the school is located and the physical planning of the school site. Where the choice of sites are limited, mitigation measures may be required to reduce the exposure to acceptable limits.

Procurement

The design and construction of schools is typically undertaken by local consultants. The work is procured through a two stage tender process. Consultants (and contractors) must first submit a company profile to pre-qualify in order to be invited to submit a fee and technical proposal. The contract is awarded to the cheapest bid rather the quality of the technical proposal.

19 MoES 2011 Policy Document – Needs for new kindergartens, schools, dormitories and gyms and options to meet them

Building Norms

Mongolia has adopted Russian Design Codes (SNIP) since the late 1950's/early 1960s'. It is unclear how well they were adhered to or otherwise implemented.

SNIP was partially translated into Mongolian for the first time in 1998. In 2006 an illustrated commentary in Mongolian containing typical seismic details was added to the Russian Seismic code. This represented the first time that a Mongolia specific modification or addition had been made. The Mongolian Science and Technological University report that this came following recognition that the Russian Code was overly theoretical and hard for Mongolian engineers to follow. As well as being difficult to follow Russian codes are also said to limit the number of engineering analysis software packages that can be used

The current Mongolian seismic code includes building importance factors for schools, which would serve to improve building seismic performance if used in the design. The code states that they are included only at the request of the project client. MACE reports that importance factors are not used for the design of government projects such as schools to try and minimize costs.

A switch from Russian based codes to Eurocodes is now being discussed.

Design Certification

Design certification is the responsibility of the CDC Validation Division, which was set up following last election in 2012. It has limited capacity and so checking is outsourced to a list of 160 experts selected by CDC based upon predetermined requirements, with Design Consultants allowed to appoint an inspector of their choosing. It is not clear how robust this process is.

Construction Monitoring

MACE report that budget cuts in the 1990s led to a drop in construction quality as inspections were curtailed, with quality of construction supervision yet to return to pre-1990 levels. CDC reports that poor build quality has led to some relatively new buildings being condemned. In response to this challenge the remit of the CDC Clients Division was expanded in 2014 such that they are responsible for inspecting construction of buildings for 4 ministries including the MoES. This is not being undertaken because capacity remains low, they only have 15 to 20 engineers who are responsible for checking projects across the country.

Assessment of Existing Buildings

Assessment of existing building stock is high on the agenda as a result of improved hazard awareness. The process for quantifying the problem and recommending actions is poorly defined and fragmented, with overlapping and unclear briefs assigned to 3 separate bodies; CDC, SIA and NEMA.

NEMA have not yet started undertaking their assessments. The purpose and methodology of the NEMA assessments is unclear but it is understood to be part of the 2010 National Program for Prevention and Reduction of Earthquake Disaster Risk.

Following a major earthquake in China a regulation was passed in 2000 to certify and create an inventory of all existing public buildings built before 2000 in order to identify their structural capacity. Each building requires a "profile" which contains non-technical information on the building to be completed and paid for by the school. As witnessed on school visits this is an A5 paper-back book with photos, typical plans, date school was built and details of routine maintenance and also larger repairs. A "passbook" is also required, which contains technical information on the building including material data. This is to be completed by a professional from CDC. This component has been delayed as it relies on material testing and lack of funds have meant that the CDC are unable to purchase the relevant equipment required.

The Special Inspection Agency (SIA) report that they have undertaken vulnerability assessments of every school in UB City, with the results held in a database. Only four (30%) of the schools visited were aware of having been inspected by the SIA. The SIA assessment is based upon the 2006 Mongolian Seismic Norm and Guidelines for Assessing Defects of Existing Buildings. Neither document is available in English. The SIA inspections utilize a series of checklists for different materials. The checklist includes detailed building element checks and a review of the general condition and deterioration of the building. It does not include the broader issues such as clear identification of lateral load system / construction typology and plan and elevation regularity. An initial review of this checklist would suggest that it lacks the ability to capture fundamental building characteristics that determine seismic performance.

As a result of these assessments the MoES reports that a total of 51 Kindergartens and 27 schools have been identified for demolition and a further 26 Schools and 50 Kindergartens have been identified as being in need of 'renovation'. The basis on which these schools were identified is unclear. Two of the schools chosen in the initial sampling study had already been demolished (Kindergarten#57 built in 1965 and Kindergarten#26 built in 1958).

The process, however, lacks a clear and transparent mechanism for making recommendations. Furthermore, it is recognized within Mongolia that the regulatory guidance and technical knowledge to design and implement a seismic retrofitting program is lacking.

Opportunity

There is an opportunity to help facilitate the planning stage by developing site selection and planning guidelines for schools. This represents a shift away from thinking about schools simply in terms of buildings/classrooms and recognizing that the vulnerability is not only dependent on the classroom construction.

There is opportunity to coordinate the assessment efforts of existing buildings and develop a comprehensive strategy for a repair, retrofit and reconstruction program that brings clarity, rigor and best practice seismic design expertise.

There is opportunity to review and make recommendations for updating the norms.

6 Conclusions and Potential Entry Points for Technical Assistance projects

6.1 Comprehensive School Infrastructure Program

The supply and demand of school and kindergarten classrooms in UB City is mismatched. Land pressure is increasing the cost of new schools whilst the MoES's budget is insufficient to meet the need as predicted in 2011, whilst donors have ceased funding construction of school infrastructure. The MoES is looking for cost efficient ways to increase capacity such as extending vertically and on plan. These extensions require appropriate planning and design to ensure that they are seismically resilient. Furthermore, existing school buildings are suffering from a lack of investment and are in poor repair with 30% being over 40 years old. The oldest 75% have little or no seismic design consideration and so vulnerability of an aging building stock is a justified concern. Initial estimates based on the field mission are that 50% to 80% of schools buildings are in need of retrofitting or reconstruction in order to address seismic vulnerabilities.

Based on the findings of this study we suggest that the World Bank/ GFDRR invest in a **Comprehensive School Infrastructure Program** which addresses the deficit in classroom capacity as well as integrating school safety. It is recommended that technical assistance is provided to help the MoES develop, shape and support the implementation of a city wide program to repair, retrofit and extend existing schools as well as constructing new school buildings.

It is recommended that technical assistance is provided to develop a **GIS database** and used to record a number of characteristics that will be assessed to determine the risk of all public school and kindergarten buildings in UB City.

This should include;

- Site information (Site plans)
- Age of building.
- Student Capacity/ Number of shifts.
- Building typology.
- Building configuration (layout).
- Building modifications that may make the school more vulnerable e.g. extensions, holes in walls.
- Structural capacity of key structural elements.
- Condition of the building.
- Non-structural systems that have an impact on the building performance in the event of an earthquake e.g. parapets, chimneys canopies.

The database developed by the SIA following their vulnerability assessments of existing school buildings could provide a good baseline of existing data. Further information from "passbooks and profiles", where they exist, should also be included. This will need to be reviewed by technical experts and may be supplemented by further vulnerability assessments and data gathering.

The RVA produced by Arup is an example of a **vulnerability assessment** that can be used to collect data but this will need to be further refined as a result of wider consultation and field testing to suit the local context.

The process can be developed into a robust and replicable assessment through technical assistance by understanding who will be undertaking the assessment and establishing quality training, reporting and communication tools. Technical Assistance should be provided by an international and/or local industry partner (firm or institution) who can partner with and provide training and support to local bodies such as SIA, CDC and NEMA who will be tasked with conducting further inspections.

Following the collection of the data it is recommended that **a prioritization risk assessment** is undertaken. This will include an analysis of the data by competent technical expertise to inform the initial planning of the School Infrastructure Program. A traffic light system (red-yellow-amber-green) (See Table 5) can be used to highlight the most vulnerable schools and prioritize actions. This will illustrate the extent of the problem and level of engagement required i.e. where a detailed engineering assessment (DEA) is required to be undertaken by technical specialists.

Table 5 Example of a traffic light system to prioritize most vulnerable schools

	School is suitably designed for seismic hazard
	School is suitably designed for seismic hazard but has some visible defects that require repair.
	School building is vulnerable to seismic hazard and a DEA may be required to inform whether retrofit, repair or reconstruction is required.
	Critical concerns with general safety of the school building. A DEA will be required confirm whether retro-fit or reconstruction (or other) is required.

Schools in poor condition due to lack of maintenance or because there is minor damage should be able to be repaired if the original design and construction (material and workmanship) is deemed safe.

Schools that are vulnerable due to poor design, poor quality materials or workmanship may be able to be retro-fitted. In some cases the building may be in a critical condition and it may not be cost effective to retrofit and the school will need to be demolished and reconstructed. These schools should be prioritized and will require a DEA.

A **DEA** is a more thorough assessment of the building which will include material testing, a review of as-built drawings (that may need to be developed), and engineering calculations to assess the safety of the school building under both serviceability and seismic loading. In undertaking a DEA a retrofitting proposal can be developed where appropriate. It is recommended that technical assistance is provided to develop a DEA process to ensure a robust, consists and rigorous approach is undertaken.

In parallel it is recommended that this data is analyzed to understand and prioritize which schools can be extended to increase their capacity. A DEA will need to be carried out on all school buildings requiring an extension.

6.2 Tools and Guidance

To support the implementation of the Comprehensive School Infrastructure Program there are further opportunities to provide technical assistance through industry partners in the preparation of tools, guidelines, and training to build capacity of the local government agencies and construction profession.

Retrofitting Guidelines

The need for corrective action to address the shortcomings of existing schools should not be overlooked. There is a lack of technical knowledge around retrofitting buildings for seismic safety in Mongolia. It is recommended that Retrofitting Guidelines are developed for local engineers that illustrate how to apply retrofitting details on a case by case basis. Details and guidelines may be grouped by construction typology.

Guidelines for Safe Extension and Modifications of School Buildings

Technical assistance is recommended to review the existing processes in place for assessing the suitability of safe vertical extensions and modifications to existing school building typologies and use this as a basis to develop guidance and training for the MoES and local engineers. The Guidelines should also include typical design details for the different construction typologies which can be adapted on a case by case basis by local engineering consultants.

Review and verification of model schools

Model schools that are appropriately designed for the seismic hazard risk in UB City can be replicated at scale and used where reconstruction of existing schools is deemed necessary. It is recommended that technical assistance is provided to undertake an independent third party **review and verification** (structural and non-structural elements) of the **MoES Model School Designs**. This process should include value engineering and design optimization to ensure the designs are cost effective and meet performance requirements including, safety, size, ventilation, temperature and light. Designs should also be assessed in terms of build ability and post-occupancy assessments. Comprehensive construction drawings, as well as material specifications, that communicate appropriately to those building the school should be produced for each of the model school designs.

Site Planning Guidelines

It is acknowledged that available sites in UB city are in short supply and that the sites are often chosen where the demand is greatest. However, once a site is chosen there seems to be no attempt to mitigate the exposure of school buildings through physical planning of the site; orientation of buildings, site drainage, avoiding steep slopes. Furthermore, as part of the MoES's need to increase capacity cost effectively they have identified schools that have space within their existing property for new buildings.

There is an opportunity for technical assistance to develop **site selection and planning guidelines** specifically for the MoES model schools to ensure mitigation measures such as civil engineering works; drainage and/or retaining walls, are provided where necessary and sites are appropriately planned ensuring that issues such as pounding are considered.

Institutional and regulatory environment

Finally, wider investment to improve the institutional and regulatory environment to achieve safe construction and retrofitting generally is needed in Mongolia. Up to date **hazard mapping** is critical and should be integrated in to **land use plans** that are enforced and incorporate the city's strategic policy for development.

Consideration should also be given to reviewing and updating the **norms and normatives** to ensure they incorporate current best practice for construction in areas subject to earthquakes. This should include an assessment of the discussed switch to Eurocodes. For this to be effective they should incorporate current understanding and best practice; reflect local forms of construction and perceptions of risk; and are part of a wider culture of safety and environmental concern that includes education and training at all levels of society, as well as legislation and enforcement.

6.3 Road Map

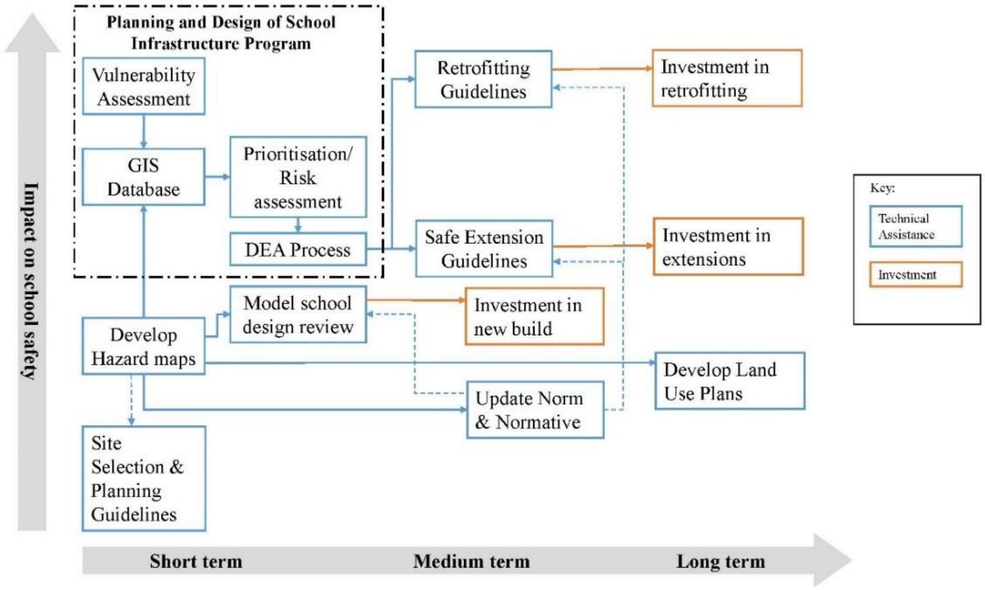


Figure 4 Roadmap

The diagram above provides a roadmap for the recommended TA WB program.

Planning and designing the **Comprehensive School Infrastructure Program** is critical to diagnose the problem and prioritize the high risk schools, hence this should be undertaken in the short term. The **risk assessment** will inform the design and development of the **Guidelines for retrofitting and safe extension** of schools.

Our findings indicate that the impact of retrofitting existing schools (where possible) will have the greatest impact on reducing the risk of existing school infrastructure in UB City. The impact of a **model school design review** depends on how many new schools are built or existing schools need to be reconstructed, and over time will increase. The number of schools suitable for safe extension are unknown but will be less than those in need of retrofit.

A **review of the model school designs** to ensure they meet international best practice standards should also take place in the short term to reduce the risk of any new school buildings being constructed. It would be advantageous, that this was undertaken once the hazard level, especially seismic level, was agreed. **Site planning guidelines** would have a comparatively lower impact on school safety but it is something that can be developed relatively easily and quickly.

It is not critical that **Norms and Normatives** are reviewed and updated in the immediate short term but when it is carried out the guidelines should be reviewed to ensure they are in line with any updates. The development of the **land use plans** will need to part of a broader strategic policy. Both, will have the potential to impact future design of all buildings.

Appendix A

Hazard Desk Studies

A1 Seismic Hazard Desk Study

Tectonic Setting

Ulaanbaatar city, with a population of 1.4 million people, is located in the central northeast of Mongolia, at the boundary between the steppe zone to the south and the forest-steppe zone to the north. Mongolia lies within the Eurasian continental plate, and is influenced by the continued ongoing collision of India with Eurasia (nearly 3000 km to the south) – Fig. 1.

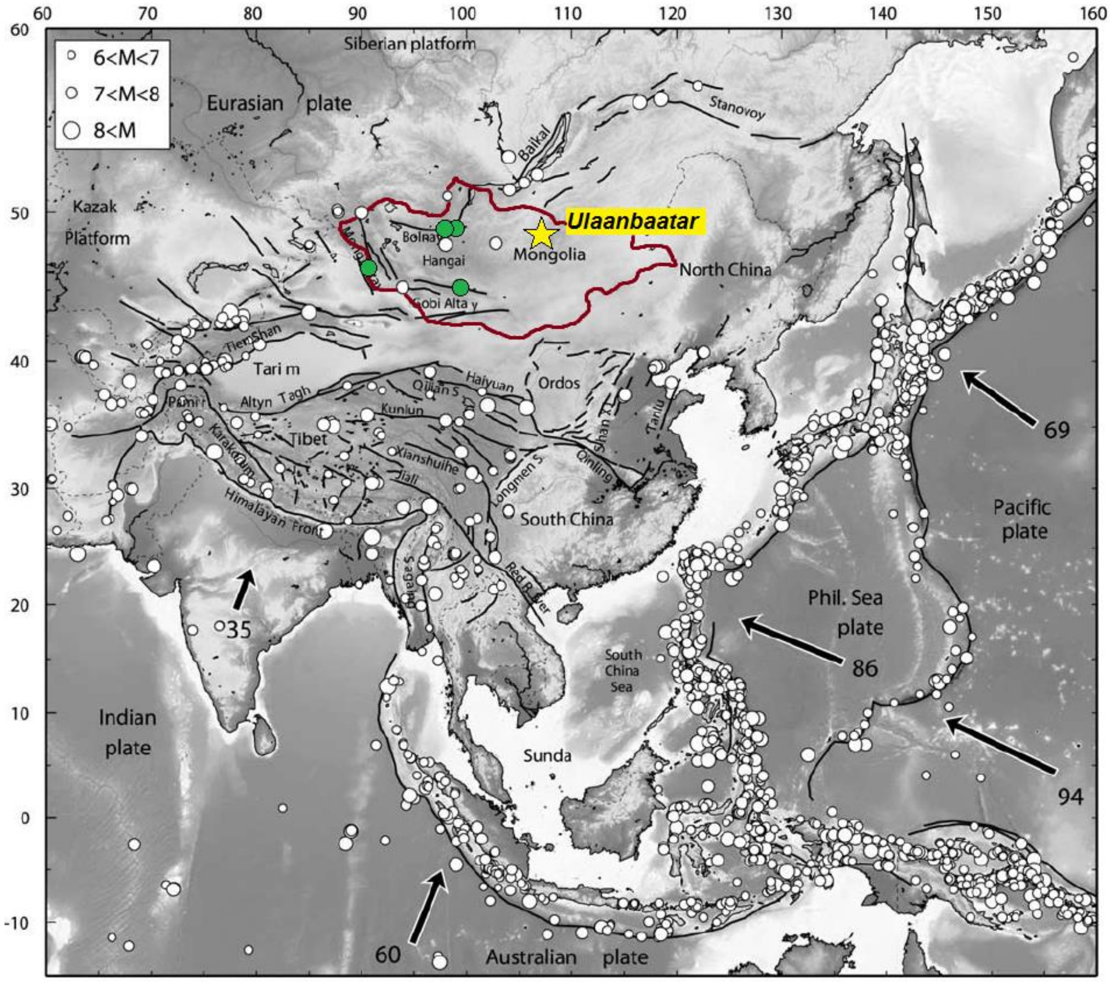


Figure 1. *Tectonic setting of Mongolia, and Ulaanbaatar, within the wider India-Eurasia collision zone (from Vergnolle, et al., 2007). Green circles show locations for the 1905, 1931, and 1957 earthquakes.*

Mongolia accommodates a small proportion of the northward motion of India, through a combination of thrust and strike-slip faulting. GPS and seismicity data indicate the majority of stain is accommodated in the mountainous western half of the country (Fig. 2); N-S shortening is accommodated by vertical axis block rotation of crustal blocks comprising the Mongolian Altay, Gobi Altay and Hangay domes (Bayasgalan, et al., 2005). Strike-slip motion between rotating blocks has given rise to very large earthquakes in western Mongolia throughout the 20th Century, including the 1905 Bulnay sequence (Ms 8.2 and 8.3) north of the Hangay dome, 1931 Mongolian Altay earthquake (Ms 8.0), and 1957 Gobi-Altay earthquake (Ms 8.3), see Fig. 1. Each earthquake occurred over 500 km from Ulaanbaatar, and therefore the respective fault systems do not represent a significant hazard to Ulaanbaator today. The largest earthquake to have occurred near

Ulaanbaatar is the 5th January 1967 event (Mw 7.0), which broke a north-south right-lateral strike-slip fault ~300 km west of the city.

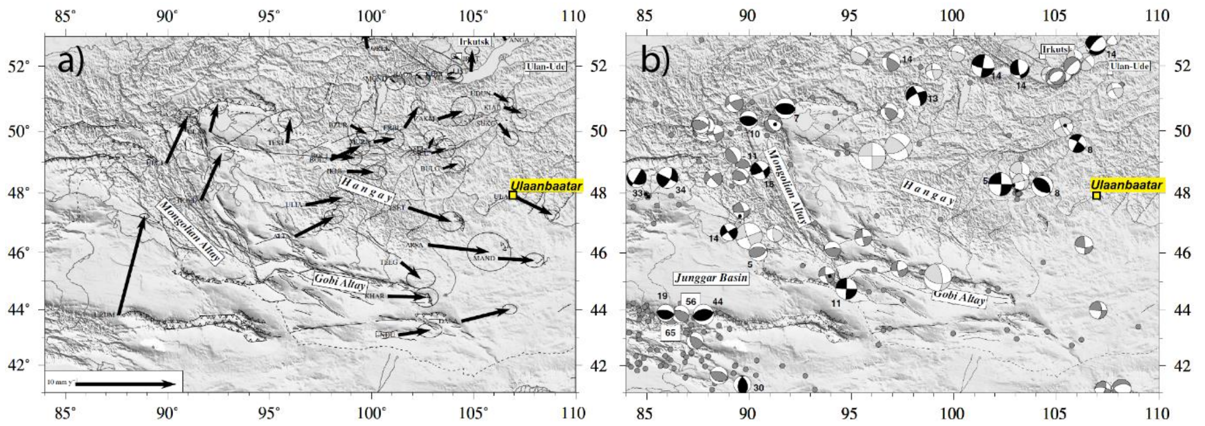


Figure 2. *(a) GPS velocities (1994-2002), and (b) earthquake locations and focal mechanisms for Mongolia (from Bayasgalen, et al., 2005).*

Ulaanbaatar is located in the relatively stable eastern half of Mongolia, eastwards of the major earthquake zones of the twentieth century (Fig. 2b). Ulaanbaatar has experienced no significant earthquakes in recent or historical time. Nevertheless, current geological research in the area has identified several active faults in the vicinity of the city, which have clear expressions in the Quaternary geomorphology. Therefore, these faults can be considered to be active, and therefore capable of producing large earthquakes. It is therefore important to understand the hazard posed to the city by these structures, both through ground shaking during the earthquake rupture, and secondary hazards, such as liquefaction and land-sliding.

Earthquake Hazard

A recent collaborative study between the Japan International Cooperation Agency (JICA) and the Government of Ulaanbaatar city (hereafter referred to as JICA, 2013) explored the impact to the city from large earthquakes occurring on various faults surrounding the city. The study evaluated the potential ground motion using a Deterministic Seismic Hazard Assessment, assuming two maximum earthquake scenarios for different target faults.

Ulaanbaatar city is located at the southern margin of the Hentei mountains, and is surrounded by the steep Bogd Khan mountain (a National Park) to the south, and the gentler sloping Songinokhairhan, Chengeltei, and Bayansurkh mountains in the west, north and east, respectively. Ulaanbaatar city is situated within the Tuul river valley, with the majority of buildings located on flat terraces bounding the Tuul river (Fig. 3). Recent growth of the city has resulted in further development on the gentler northern slopes of the city, and in the tributaries of the Tuul River. The geology of Ulaanbaatar is comprised of lower Paleozoic Hara Formation, middle-upper Paleozoic Henei Formation, Mesozoic granites, Cretaceous Zuunbayan Formation and Cenozoic sediments (Takahashi, et al., 2004), which form the bedrock mountains. Quaternary fluvial deposits (sands, gravels and muds) form the base of the Tull river valley and its banks.

Three active faults have recently been identified in the region surrounding Ulaanbaatar (Demberel, et al., 2014): the Hustai, Emeelt and Gunjiin faults (red lines in Fig. 3). It should be noted that the Gunjiin fault lines up with an eastward projection of the Hustai fault. This raises the possibility that an active fault may lies directly beneath Ulaanbaatar city itself (linking the Hustai and Gunjiin faults), although there is currently no observational or geophysical evidence to support this hypothesis. Because earthquake magnitude scales with fault displacement, and fault dimension (i.e. longer faults can host larger earthquakes), using fault scaling relations of Wells and Coppersmith (1992), we can estimate the maximum earthquake for each of the Ulaanbaatar faults based on their length. Using this approach, the JICA (2013) report estimated maximum magnitudes of Mw 7.6 (Hustai fault), Mw 7.0 (Emeelt fault), and Mw 6.6 (Gunjiin fault). Results from paleoseimology trenching studies for each of these faults are pending (Ferry, et al., 2010).

JICA (2013) explore two earthquake scenarios: (1) Mw 7.6 on Hustai fault, and (2) Mw 7.0 on Emeelt fault and Mw 6.6 on Gunjiin fault. The analysis uses an attenuation law of Kanno, et al. (2006) to estimate Peak Ground Acceleration (PGA) across the city (Fig. 4.) The results from both scenarios are similar, and indicate PGA values across the city ranging from 0.3-0.43 g (300-450 gals).

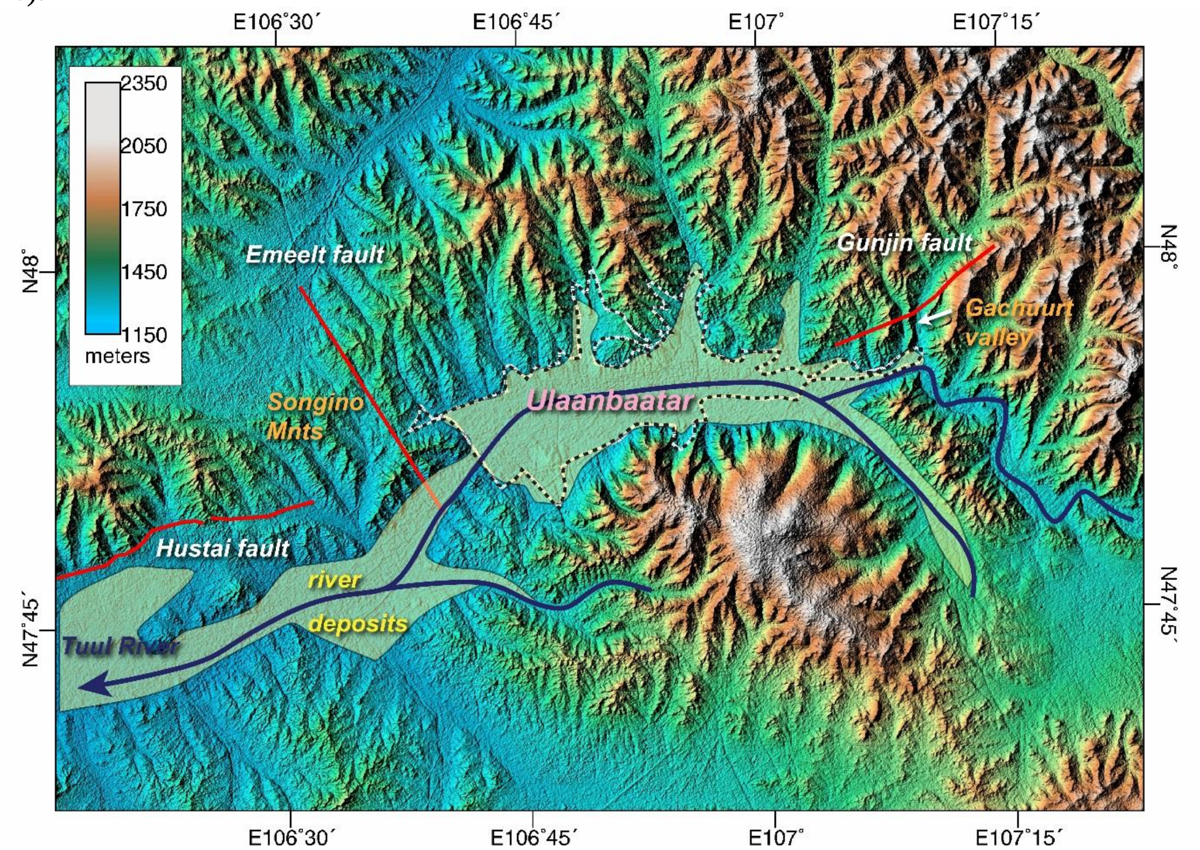


Figure 3. *SRTM topographic map of the Ulaanbaatar region. The city lies on the riverbanks of the Tuul River, which drains west from the Hentei ranges. Dashed black and white line shows the approximate limits of the city. Red lines show active faults in the area.*

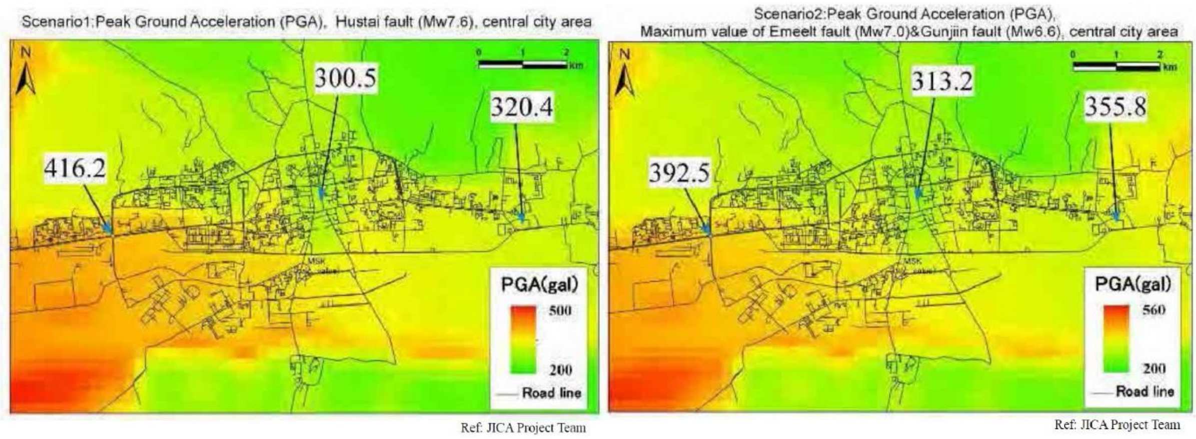


Figure 4. *PGA for earthquake scenarios (1) and (2) from the JICA (2013) report.*

The largest hazard is in the western half of the city, and comes from the Emeelt fault, which, despite producing smaller magnitude earthquakes than the longer Hustai fault, is located closer to the downtown Ulaanbaatar.

Landslides and Liquefaction

JICA (2013) conducted a limited ground survey to determine the risk of liquefaction during ground shaking. Using microtopography classification, boring surveys and soil tests across several locations in the city, they found a low possibility of liquefaction, due either to a high soil density or distribution of soil grains being outside of the liquefaction condition. Nevertheless, they note that a more comprehensive analysis is required to assess liquefaction potential in higher groundwater areas along the Tuul River.

JICA (2013) also conducted a landslide susceptibility evaluation based on the two tested earthquake scenarios (specifically the predicted PGA values throughout the city), and slope angles computed from digital topography (30 m ASTER-derived GDEM). Potential high susceptibility to land-sliding is found close to the source faults (which are all located outside the main city), and on very steep slopes within the mountains either side of Ulaanbaatar. Little hazard exists within the flood plain on which the majority of Ulaanbaatar is located. Hazard is higher in low-density satellite communities on the mountainous outskirts of the city, to the west in the Songino mountains, and to the north east near Gachuurt.

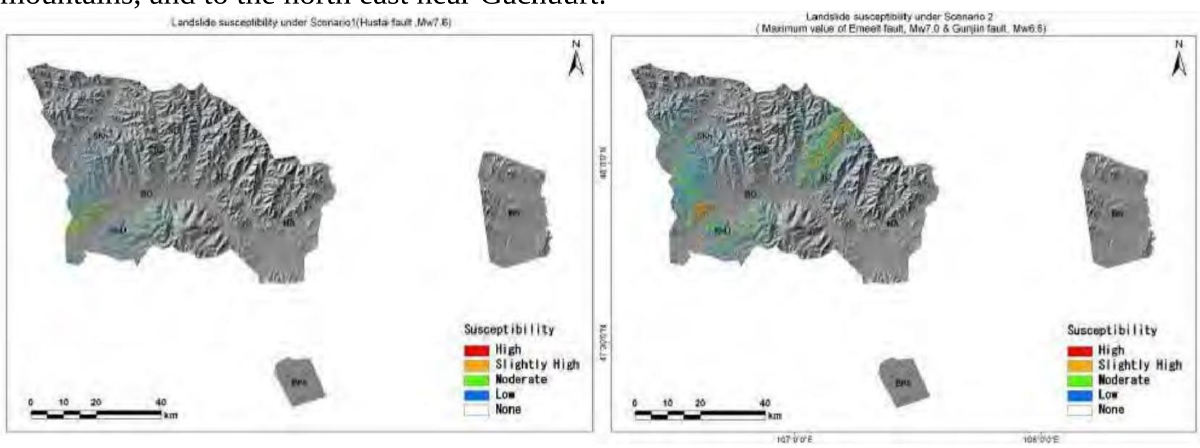


Figure 5. *Landslide susceptibility map for Ulaanbaatar region for (left) scenario (1), and (right) scenario (2) earthquakes.*

Building design

In Mongolia, the seismic code of the former Soviet Union was used directly from 1960-1991, which is based on maximum intensity. From 1992 onwards, Mongolia introduced its own seismic code. An evaluation of buildings throughout the city by the Ulaanbaatar government in 2011-2012 found brick masonry buildings constructed before 1971 were of low quality, while those constructed after 1971 needed strengthening work. Furthermore, precast concrete buildings constructed between 1965 and 1980 also need strengthening work. The majority of buildings constructed using reinforced concrete were thought to have a reasonable seismic capacity (JICA, 2013). Nevertheless, JICA (2013) note the lack of quality control in construction projects in Ulaanbaatar, even for new buildings, which has resulted from the pressure to deal with the rapid increase in population in recent years.

Design response spectrum for sites across the city vary according to the specific site condition. First order estimation of site class across the city can be made from global VS30 maps (average shear-wave velocity down to 30 m) available from the USGS. High shear-wave velocities are typical of rigid bedrock, while lower velocities are typical of softer and weaker soils which amplify ground shaking. (VS30 maps are based on slope angles derived from digital topographic datasets). Figure 6 shows the site classification for Ulaanbaatar based on the global VS30 map (black squares highlight school locations), while Figure 7 shows a similar VS30 map based on ground survey data collected in the field (JICA, 2013). The two datasets yield similar results, although ground survey data suggests site class C may actually be appropriate for the entire area spanning the Tull river and its adjacent banks, on which the majority of Ulaanbaatar is built (i.e. encompassing both class B and C areas in the global VS30 model).

Figure 8 shows the ASCE-705 design response spectrum for buildings constructed in class B and C sites. Each curve shows the spectral response acceleration values for ground motions having 10 percent probability of being exceeded in 50 years. Spectral accelerations at 0.2 s and 1.0 s, for 5% of critical damping, based on the probabilistic 10%-in-50-year peak ground acceleration (PGA) values from the Global Seismic Hazard Assessment Program (GSHAP).

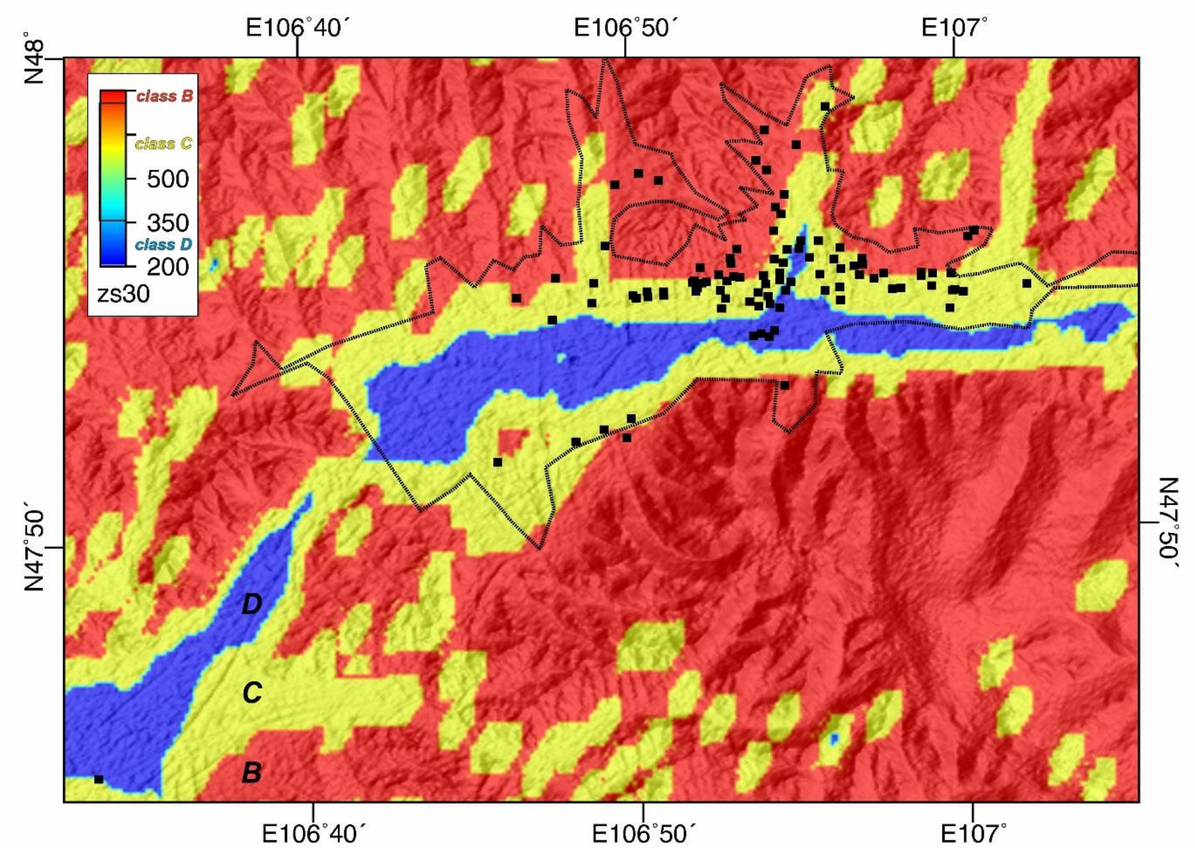


Figure 6. *VS30 map (from global USGS dataset) for Ulaanbaatar. School sites are shown by black squares.*

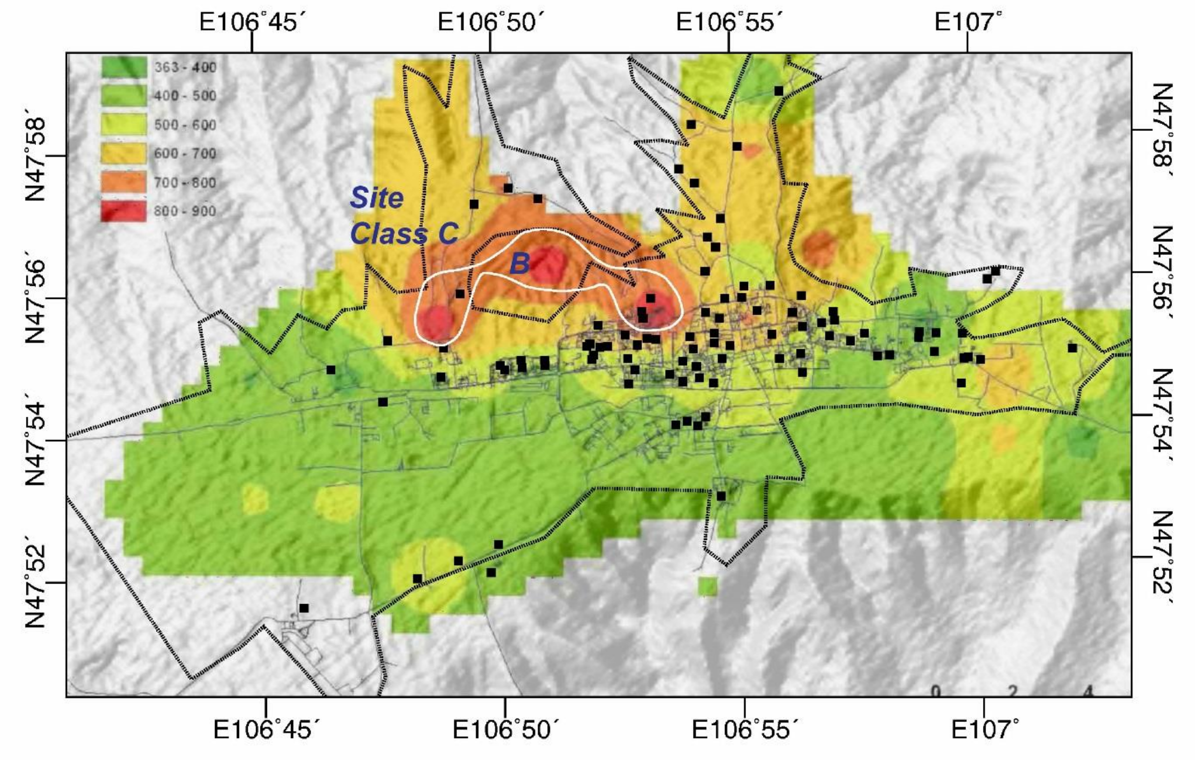


Figure 7. *VS30 map (from ground survey data collected by JICA, 2013) for Ulaanbaatar. School sites are shown by black squares.*

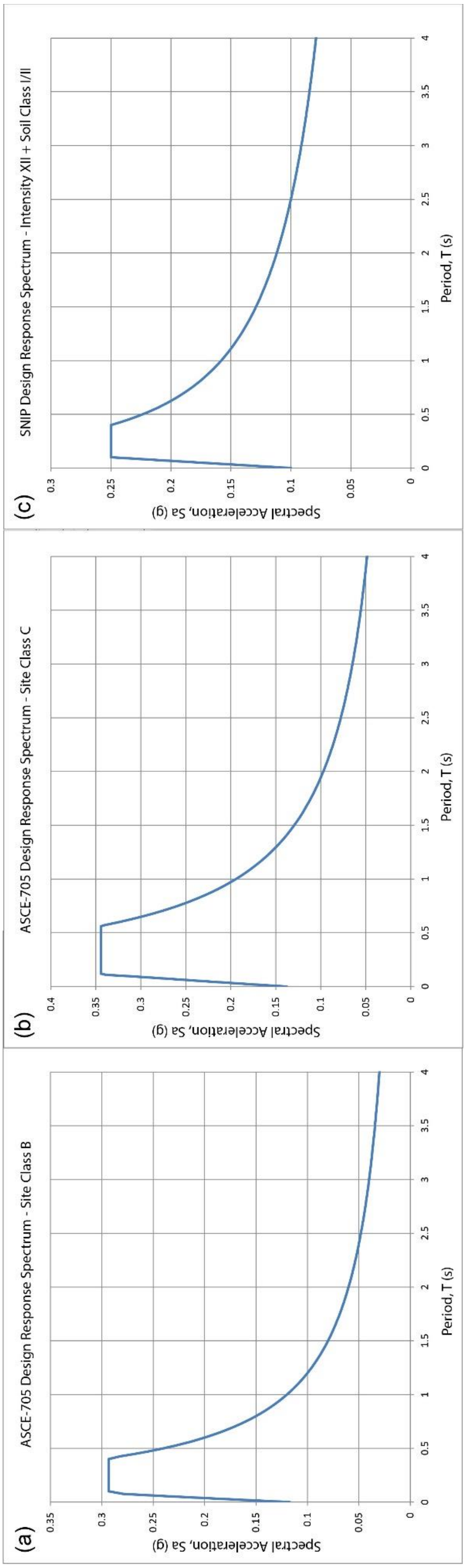


Figure 8. *ASCE-7 and SNIP design response spectrum (10% probability of being exceeded in 50 years) for site class B, C and MSK intensity VII.*

A2 Flooding Hazards Desk Study

1 Introduction

Flooding has been identified as a potential hazard to schools in Ulaanbaatar. The city has experienced severe flooding on a number of occasions. The most recent serious floods occurring in 2009, when 24 people are known to have died and hundreds rendered homeless. The city's vulnerability to the impacts of flooding is greatest in areas where urbanisation has occurred informally. Flood risk in the city is a function both of the city's growing population and of the presence of numerous watercourses - from the River Tuul, which flows along the base of the valley, to the numerous minor drainage channels which drain southwards into the city from the mountains to the north.

This brief memorandum is designed to provide brief background and a concise overview of the key issues that would need to be considered both by those assessing the vulnerability of existing schools to flooding or those planning a programme of new schools.

2 Flood Risk Concepts

2.1 Risk

Flood risk can be defined as:

$$Risk = f(Hazard, \mathrm{I}mpact)$$

It is a combination of the probability of the flood hazard occurring and the magnitude of the potential consequences of a flood. The consequences of flooding will depend upon the nature of the flood hazard and the vulnerability of an area. The nature of the flood hazard affects the potential for the flood to cause damage. The vulnerability of a flooded area affects the potential for damage to be caused and will be influenced by factors such as:

- The number of properties and/or size of area affected
- The type of development (eg more damage would be caused during the flooding of a supermarket than during the flooding of a park)
- The nature of the population at risk (eg elderly or infirm people are more likely to suffer during flooding)
- The presence and reliability of mitigation measures to manage flood

The combined influence of these factors will determine flood risk at a site. An assessed high risk of flooding, implying the need for mitigation measures, could arise from a very severe flood event with a low probability or a much more probable, and therefore (on average) more frequent, flood event which causes less damage and disruption.

3 Scope of Work

Scope of brief piece of work was to; 1 to provide a background to the nature of the flood risk issues in Ulaanbaatar; 2 to provide a rapid assessment tool/checklist that can be used to identify the relative vulnerability of existing schools; 3 to provide an improved base plan (s) to guide the assessment.

4 Background to Flood Hazards in Ulaanbaatar

4.1 Relevant aspects of the physical and hydro-meteorological environment

Figure 1: Map showing location of Mongolia and Ulaanbaatar

The city lies at an elevation of about 1,310 metres in the valley of the Tuul River, which is a tributary of the River Selenge. This valley is orientated East-West and is at the foot of the mountain Bogd Khan Uul at the boundary between the steppe zone to the south and the forest-steppe zone to the north. The steep valley sides sloops down to a broad, largely flat valley bottom. The city occupies the land on the north side of the tiger Tuul and extends up the slopes to the north.

The confluence of the rivers Selbe and Tuul are within the city boundaries. The Tuul then flows west initially before draining North into Lake Baikal in Russia.

4.2 Specific Flood Hazard Information

In Mongolia, severe winter weather events are known as 'zuds'. There are different types of zud, all of which result in severe weather conditions. No snow in the winter can lead to drought because the spring thaw is an importance source of water. If it is too cold animals need to conserve energy instead of feeding and freezing of ground surfaces restricts access to grass. Of most relevance to flood risk is the white zud. This is where a greater than average volume of snow accumulates over the winter months. This can lead to spring floods, which last from mid-April to May and can form up to 20-60% of annual run-off within the river systems. Figure 2 illustrates how the spring thaw affects seasonal river flow rates.

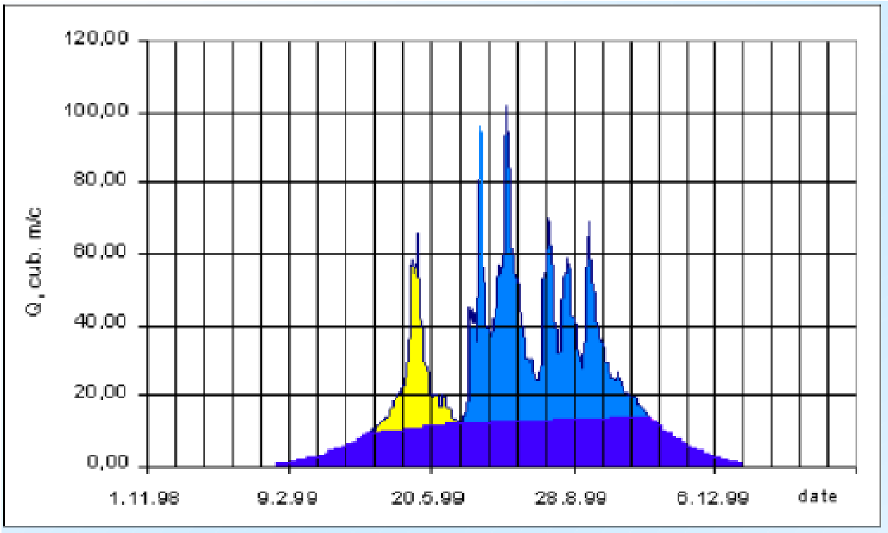


Figure 2: Typical Flow Hydrograph of Mongolian rivers (river Tuul,Ulaanbaatar, after G.Davaa)- yellow indicates spring flood and light blue, rainfall (Oyunbaatar)

Annual mean precipitation varies from 50mm in the south to 400mm in the north. 85% of the annual precipitation in Ulaanbaatar, which averages 267 millimetres, falls from April to September, of which about 50-60% falls in July and August. Although annual precipitation is low, its intensity can be high. The maximum precipitation (138 mm/day) recorded since 1940 occurred on 5 August, 1956 at Dalanzadgad, and the second greatest (121 mm/day) on July 11, 1976 at Sainshand. It is possible, however, that an intense rainstorm of 40-65 mm may fall in a single hour. This makes Ulaanbaatar susceptible to flash flooding caused by short duration high intensity storms over small, urbanised catchments.

The low winter temperatures and overall average temperature of −0.4 °C means that the city lies in the zone of discontinuous permafrost. This has a number of implications as follows:

1. The principal permanent buildings in the city occupy the areas where the soils periodically do thaw – i.e. on the north side of the valley, which has a southern aspect. These areas are now largely developed;
2. Building is difficult in areas where aspects precludes thawing in the summer. Development of these areas generally comprises traditional yurts that do not have foundations that protrude into the soil.
3. Any rain that falls in areas of frozen ground cannot soak away and immediately appears as storm runoff.

Thus the flood hazard is characterised by two key phenomena:

1. High river flows caused by spring snowmelt. This runoff generating mechanism is likely to occur slowly (relative to high intensity rainstorms) over wider areas and is therefore likely to affect the larger river systems such as the Tuul and Selbe. These floods are likely to be characterised by major flows in these key river systems that come out of the main channel in to the floodplain. These floods are, in principle, easier to forecast and for hydrologists to provide warnings to those potentially affected.
2. Flash flooding caused by intense localised storms. Such storms are most likely to cause flooding on small catchments, such as those draining the slopes on the valley sides above Ulan Bator. These areas of the city are extensively occupied, including large areas of

informal settlement comprising yurts and wooden buildings. Flash floods of this kind can be very challenging to forecast and providing advance warning to those affected would really require use of weather radar. Many of the drainage pathways are dry under normal conditions and those who have placed their property in the path of these ephemeral watercourses may be unaware of the risks.

There are few areas of the city that are not susceptible to the above flood mechanisms to some extent. The hazard however is concentrated along the branches of the natural drainage network. The city centre appears to be afforded protection by a system of lined channels designed to convey floodwater through the urban area into the River Tuul. This formal drainage system does not appear to extend far beyond the city centre.

4.3 Historical Flooding Incidents

Below are some examples of significant historical flood events:

- 10th-11th July 1966: Tuul river basin in Ulaanbaatar recorded a daily rainfall of 103.5 mm (about 43% of total annual precipitation. Flood water velocity in the Tuul reached 4-5 m/s; flood discharge was 1700 m3; and water levels rose upto 151 cm within 1 day. The river rose 3.12 m against its usual level, killing 130 people and causing 300 million togrogs (7.4million USD) worth of damage.
- 15th August 1982: a high intensive rainfall of 44 mm (84% of monthly rainfall) occurred over a 20 minute period. It lead to flash floods along 42 ephemeral beds and small rivers around the city (mainly from the northern side) and killed several tens of people and caused property damage and loss.
- 18th July 2003: total amount of rainfall within 3 hours was 22.7 mm at the Takhilt meteorological station and 54 mm at the University meteorological station. Flash flood discharge along the ephemeral river beds varied from 8 - 17.5m3/s. The floods caused 10 deaths and destroyed 2 km of paved roads as well as 30 shelters.
- In the Bayangol district, flash floods are dominant and there have been 18 flash floods from 1996 – 2005, resulting in the loss of 56 lives and a lot of property damages.

Since systematic and permanent observation for river water regime started, in 1966-67, 1971, 1974, 1976, 1982, 1984-1986 several huge floods along the Selenge, Delgermuren, Onon, Orkhon, Tuul, Kharaa and Eroo (N. Dashdeleg, 1987) have occurred. In recent years, there have also been high flows in1988, 1989, 1993-94.

4.4 Hydrological Monitoring

There are 126 hydrological gauging stations in the country and 50 of them transmit operational data for flood control. These stations are shown below in Figure 3. In addition there is a Doppler style radar station (by JICA, 2002) located at the top of Morin Uul hill near the airport, which is situated 16km from the centre of town in the South Western part of Ulaanbaatar.

There are two meteorological stations situated in Ulaanbaatar, one at the University and one Takhit.

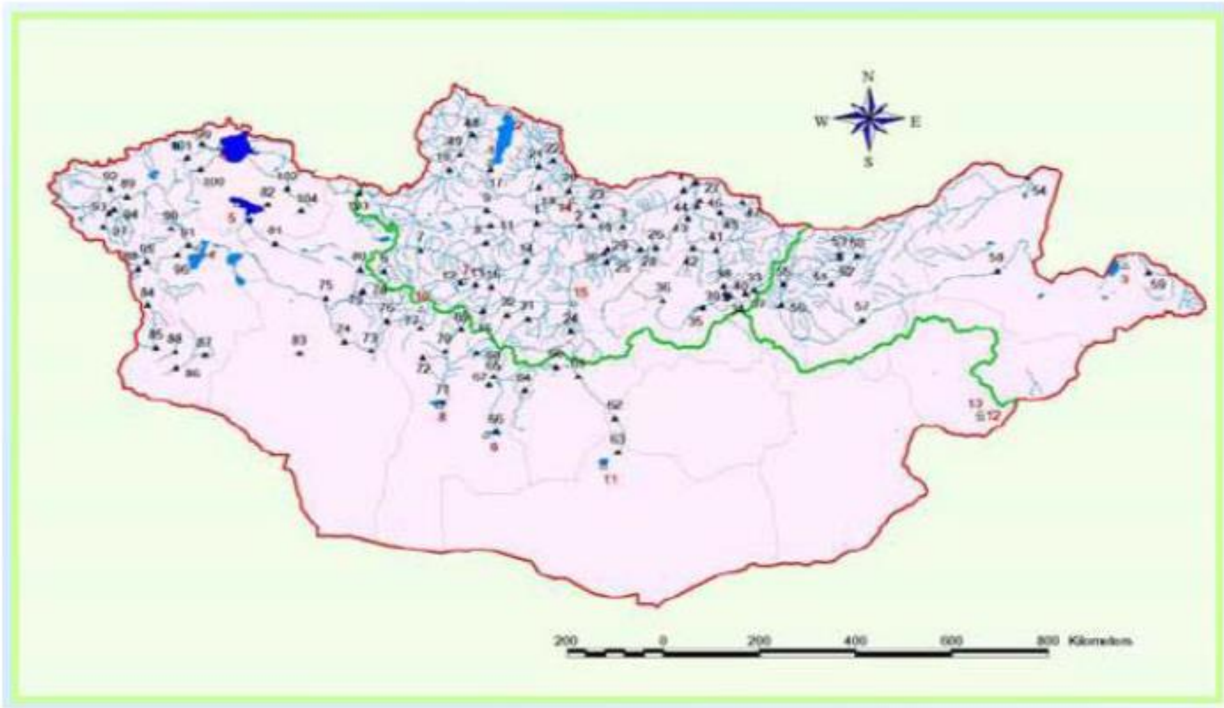


Figure 3: Map showing the locations the 126 hydrological gauging stations around the country

9 maps of Ulaanbaatar have been generated (1 overview and 8 zoomed in sections) showing: the locations of schools, kindergartens and hospitals; the main waterbodies; and the flood zones showing 10cm, 30cm, 100cm and 200cm water levels. These can be used when on site to get an orientation of the surrounding area. We note that the flood zones have been generated by others, and in some locations the floodplain is has straight edges which may be indicative of errors in digitisation (north end of Drawing No. 003).

5 Review of Guidelines on Flood risk Mapping

Rabindra Osti, an International Consultant, has written a Guidelines on Flood Risk Mapping of Ulaanbaatar City for The Ulaanbaatar- Clean Air Project (UBCAP) as part of a Disaster risk management improvement project in Mongolia. The draft report was published on the 26th of July 2014 and is a high level method statement for her proposed work.

This report defines risk as:

$$\boldsymbol{R}isk = \boldsymbol{H}azard \times \boldsymbol{E}xposure \times \boldsymbol{V}ulnerability/\boldsymbol{C}apacity$$

Although the equation is slightly more complex, it follows the general principal of risk based flood analysis; therefore the process behind the method statement is sound. The method statement proposes hazard mapping for a variety of scenarios including one for climate change. When mapping the four categories of indicators the indicators and sub-indicators will be indexed; however the process has not been expanded upon in detail.

There are concerns about the implementation of the method statement because it is very high level and the details have not been specified. The following are some of the issues that have been raised:

- How will the work be carried out?
- When surveying, will all the rivers be surveyed? If not, which ones?
- How will they be chosen?
- What are the distances between the cross sections?

The methodology seems to be based upon generating cross sections of rivers, which will only address the issue of fluvial floods. In addition, surveying rivers may be very time consuming due to the large number of rivers present in Ulaanbaatar. Therefore instead of or in addition to taking cross sections across rivers a LiDAR survey of the flood plain may be more suitable.

The centre of Ulaanbaatar is situated in a valley surrounded by very high mountains and parts of the city is situated in the lower slopes of the mountains; therefore surface water flows due to rain and snow is very likely and the surface water flooding may not be accounted for if the risk mapping us purely fluvial based.

The report identifies sediment as a problem and quotes that '60% channel capacity is reduced due to sedimentation' therefore this may be a critical issue. The report does not however identify the methods and calculations used to calculate the sediment loads. In light of this it should be borne in mind that sedimentation is highly likely due to surface water flows and therefore the capacity of structures may be reduced.

The proposed output of the project will be a grid of Ulaanbaatar identifying the risks for each 90m by 90m square (from the equation). The risk map will be demonstrating the risk of flooding due to fluvial hazards of the surveyed watercourses. These risk estimates will however not account for the other sources of flooding such as surface water run-off, and may therefore overlook significant sources of flood risk. Therefore, one of the main questions is, how will the risk mapping account for flash flood hazards and overland mechanisms, which has been highlighted as a key problem of Ulaanbaatar.

6 Conclusions

Therefore in conclusion there are two main flooding mechanisms at play in Ulaanbaatar:

1. flooding from primary river systems caused by rapid snowmelt
2. flash flooding from minor and ephemeral watercourses

These mechanisms form different challenges in terms of the types of impacts they have on the built environment and the ease of forecasting and providing early warning of their occurrence. Specifically the flash flooding risk is as much about overland flow as it is about flow along ephemeral watercourses. This makes it as important that the relative elevation of the schools (school floor levels) is considered relative to local ground levels as much as it is to local waterbodies, ditches and drains.

Appendix A contains a checklist, which can be used when on site at a school to assess the susceptibility of the school to flooding (and if so which type) and to assess the level of damage it may concur and how resilient it may be. The intent of the questions is to prompt the discussion and the rapid risk assessment of the school.

The maps do not take account of the overland flooding mechanism – if a site is outside of the floodplain areas depicted, it does not mean that it is safe. In particular if a site is downslope of an identified area of flooding and there is no obvious barrier to flow, it may be at risk of flooding.

Appendix B

Documentation Register

B1 Documents Received

Fact sheets/ brochures/ articles	**ADB Mongolia Fact Sheet**
	CDC Overview
	MACE Overview
	JICA Education facilities project completed
	NEMA School survey presentation
	WB funded schools - Schedule for opening ceremonies
	MoES Needs For New Kindergartens Schools Dorms Gyms And Options
	UB Post - Parliament Approves State Budget For 2015
Codes/ Guides	Flood Risk Assessment and Preparation of Flood Risk Management Strategy
	List of Construction Norms and Normative Documents in Effect
	The following in Mongolian only:
	Building code of construction and planning in seismic zones
	Guidelines for assessing defects of existing buildings
	Guidelines for evaluation of seismic resilience of existing buildings
Checklists/ Surveys	SIA Checklist 5.11 - Inspection of construction operation work of concrete buildings
	SIA Checklist 5.12 - Inspection of construction operation work of brick buildings
	SIA Checklist 5.13 - Inspection of assembling process of prefabricated building
	SIA Checklist 5.2 - Monitoring check list of utilization of the existing buildings
	Construction Survey
	Earthquake Disaster Assessment

Appendix C

Mission Details

C1 School Visits

Sampling

A list of 245 Schools[20] was provided by the World Bank Task Team. With 4 to 5 days available for RVA's a sample size of 15 was chosen using an online sample size calculator[21], giving a confidence level of 90% and a margin of error of 20%.

The schools were selected using stratified random[22] sampling where by the data was stratified into 4 categories, with each category represented proportionally in the sample:

1. School type (Kindergarten or Primary/Secondary)
2. Location (District)
3. Construction Methodology (Load bearing masonry/Reinforced Concrete Frame/Timber)
4. Year built (pre 1975, 1975-1995, post 1995)

In the event the number of days available for surveying was reduced whilst the size of the schools precluded more than 3 assessments per day. In total 9 schools and 12 buildings were subject to an RVA, as at 3 schools 2 buildings were assessed. Care was taken to maintain the proportionality of the stratified sample. A further 6 schools were visited externally without conducting a full RVA.

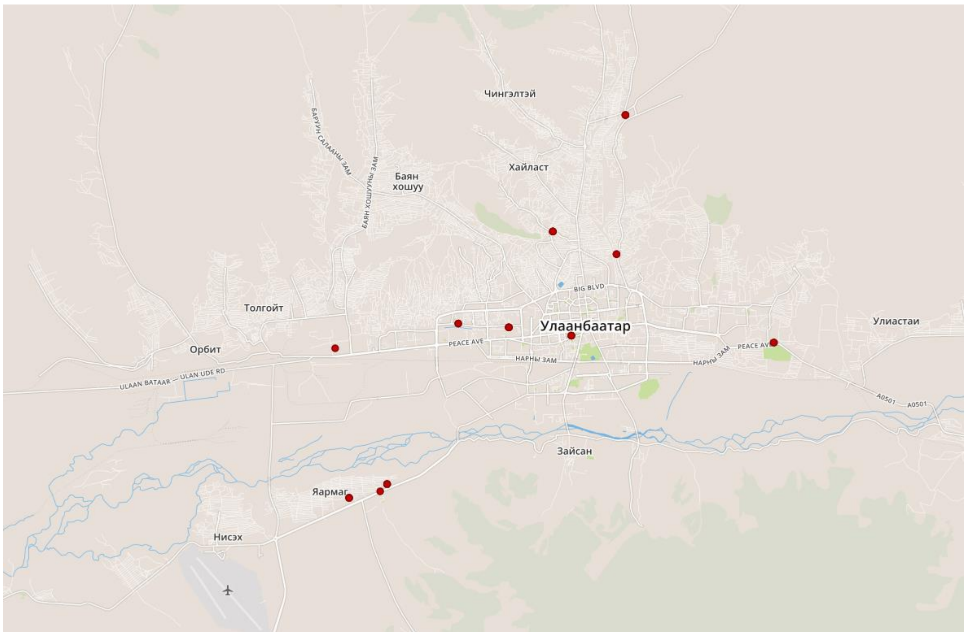
Location

The location of the schools visited are marked on the maps below

[20] Data o kindergarten and schools of UB city_English.docx

[21] http://www.raosoft.com/samplesize.html

[22] http://www.investopedia.com/terms/stratified_random_sampling.asp


Чингэлтэй
Хайласт
Баян хошуу
Толгойт
Орбит
Улаанбаатар
Улиастаи
Зайсан
Яармаг
Нисэх
PEACE AVE
BIG BLVD
НАРНЫ ЗАМ
ULAAN BATAAR – ULAN UDE RD
A0501


Улиастаи
PEACE AVE
A0501
Налайх

Appendix D

Rapid Visual Assessment

D1 RVA Methodology

The RVA Assessment was based on the methodology outlined in the Arup Report 'Assessment and Delivery of Safe Schools'[23] which is highlighted in the pages below.

The RVA was developed through a documentation review of the following documents and existing assessment tools;

Agha Khan Development Network (2013) Integrated Rapid Visual Survey for Habitat Improvement

Agha Khan Development Network (2013) Rapid visual screening method-Level 1

Arup (2014) Arup Inspect, Bangladesh Ready Made Garment Factory Inspections

Arup (2007) DEC Tsunami Appeal FEMA 154 adaption

FEMA (2002) FEMA 154. Second Edition, Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA (2010) FEMA P-424 Design guide for improving schools safety in earthquakes, floods and high winds

GFDRR Guidance notes on safer school construction

GNDT (1997) Italian method - 1st level Damage Form For Damage Evaluation

Homeland security (2011) Integrated Rapid Visual Screening of Buildings

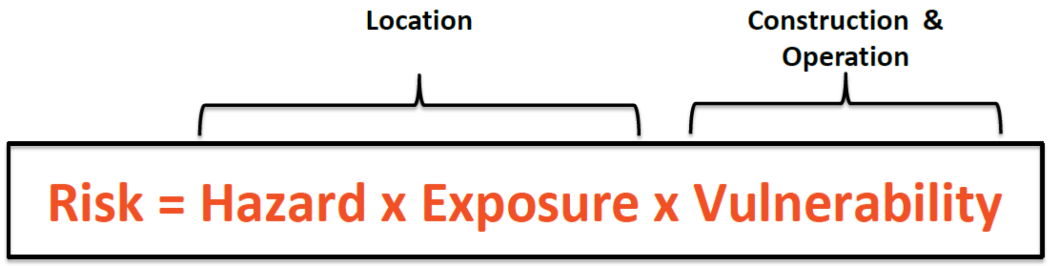
NZSEE (2006) - Initial Evaluation Procedure

UNICEF (2011) Towards safer schools

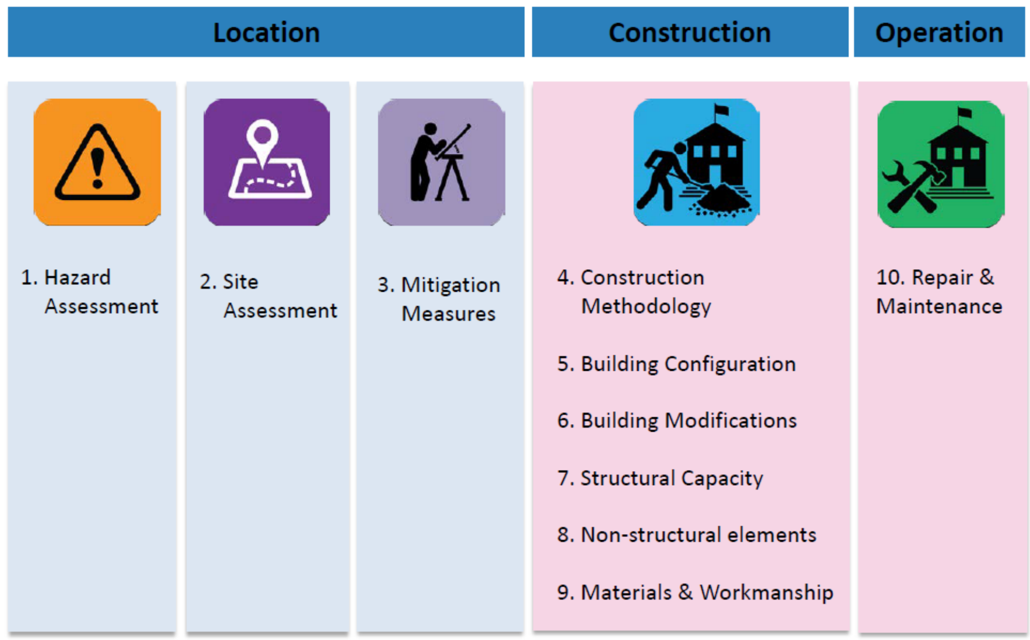
UNESCO (2013) VISUS Method Handbook

The generic RVA questions were further refined and developed into a country specific tool prior to the mission based upon the hazard desk study.

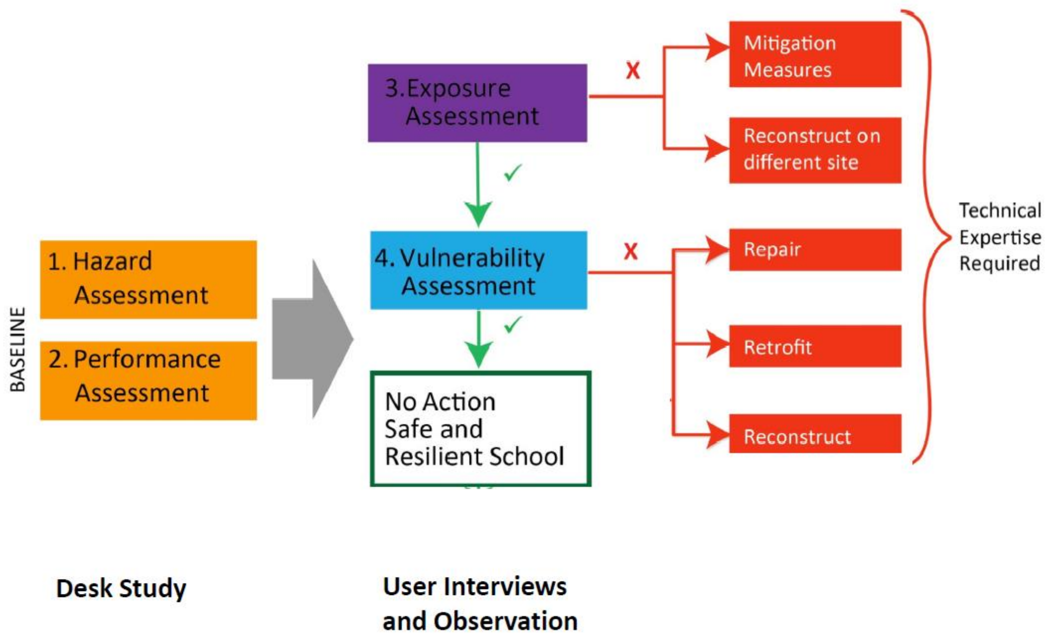
[23] Assessment and Delivery of Safe Schools, Arup December 2013 (developed on behalf of GFDRR to inform the final design of GPSS)



Characteristics of a Safe School



Assessment Process



3.Exposure Assessment

- **Site Assessment**
- **Physical Planning**
  - Civil Engineering Works
  - Building Form and Communication

4. Vulnerability Assessment

- **Construction Methodology**
- **Building Configuration**
- **Modifications**
- **Structural Capacity**
- **Structural Deterioration**
- **Non-Structural Elements**
- **Maintenance and Repairs**

D2 RVA Questions

The Arup team used Fulcrum[24], a web based data collection App to design a RVA form that could be used during the school visits to collect data.

User Interview

No.	Heading	Sub heading	Question
1	**Survey details**	**Background info**	School Name:
			Date Surveyed:
			Time surveyed
			Survey No.
			Arup Surveyor Names:
			Local Surveyor Names:
			Address:
			District:
			Photo of main entrance :
2.1	**User Interview**	**Contact details**	How many school contacts?
			Contact Name:
			Contact Position:
			Contact's Duration in Post (years):
			Contact Email:
			Contact Phone:
			Photo of Contact (if appropriate):
			Other contact details will be entered. Up to three maximum.
2.2	**User Interview**	**Site Management**	Number of buildings on site:
			Number of pupils/staff on site:
			Are site drawings available?
			Is a soil report available?
			What is the historical function of the site?
			Is the school public or private?
			Public
			Private
			Is there someone in charge of maintenance?
			Is it different from the school contact person giving the interview?
			Does the school have a maintenance budget?
			Are construction skills available locally for maintenance?

[24] http://fulcrumapp.com/

			Are the materials required available locally?
			Is the landscaping/surrounding area maintained?
			Does the site have a drainage plan?
			Does the drainage plan consider natural drainage systems and additional requirements due to run off?
			Are drainage systems regularly cleaned and maintained?
			Where are vulnerable/ valuable items stored?
			Where do utilities enter the site?
2.3	**User Interview**	**Previous site issues**	Has there been any history of flooding on the site. If so please describe it.
			Last flood event (year):
			Maximum historical flood height (m)
			Does the site have a high water table?
			Have you felt tremors? How frequent and how severe are they? What impact has it had in the school?
			Is there an evacuation procedure?
			Is there a procedure in place to recover from the impact of hazards?
			Initial comments/reaction to interview (Key concerns, if any)
2.4	**User Interview**	**Building**	Name or number of building:
			Function of building:
			Auditorium / Gymnasium
			Cafeteria
			Classrooms
			Maintenance
			Offices
			Other
			Number of pupils/staff in building
			Number of basements
			Number of floors (including ground floor and roof - if used)
			Construction year?
			Name and contact details of building engineer
			Name and contact details of building architect:
			Are drawings available for the building?
			Is there a building permit? (Approval authority, permitted use, permitted size of bldg)
			Have there been any recent additions, refurbishments, extensions, or addition of floors?
			Change in use (increased floor or roof loading)

			Change in cladding material
			Change in internal/ external wall layout
			New openings in internal/ external walls
			New opening in floors/ roof
			Additional external canopies
			Additional stories)
			Extension on plan
			Other
			Year of refurbishment:
			Are any additions, refurbishments, extensions, or addition of floors planned?
			Have you carried out any structural repair work after construction? (i.e. cracking repair, re-plastering work)
			Historical function of the building (original purpose):

Site Exposure

3.1	**Site Exposure**	**Topography**	Is the site on a slope?
			Is site elevated above the surroundings?
			Is the site at or near the base of a slope/ escarpment ?
			Are there deep cuts into the hill/slope?
3.2	**Site Exposure**	**Proximity to water**	Is any part of the site located in an area identified as being at risk of flooding by available flood hazard maps. (Give flood hazard map reference.)
			Is the site away from a river/ body of water?
			Distance to a river/ body of water:
			Is the site elevated above the floodplain/ body of water?
			Give height above floodplain/ body of water if known.
			Is there evidence of historic flooding on site?
			Is there a dry channel in or nearby the site?
3.3	**Site Exposure**	**Faults / soil conditions**	Are there any linear features or vertical offsets on the site, which could indicate an active fault?
			Are their signs of heavy erosion on the site?
3.4	**Site Exposure**	**Vegetation**	Is the site sheltered from wind? (e.g. with natural wind barriers - trees)
			Is there vegetation on site?
			Is there significant hard landscaping on site?
			Are there large trees on or near the site that can blow over?
3.5	**Site Exposure**	**Mitigation Measures - Water**	Are there any man-made drainage systems/ culverts on or near the site?
			Are the drainage systems/ culverts upstream or downstream of the site?
			Have the drainage systems/ culverts ever overflowed/ been prone to blockage?
			Are there any flood mitigation measures?
			Flood barriers/ defenses on site or at source of flood?
			Permanent / temporary water exclusion measures
			Flood storage areas on or near the site
			Flood control structures (flap valve, sluice gate) near the site
			Temporary water diversion for severe flooding to an pre-identified safe area
3.6	**Site Exposure**	**Mitigation Measures - Topography**	Is there any evidence of slope stabilization?
			Are there any earth retaining structures on or near the site?
3.7	**Site Exposure**	**Mitigation Measures - Planning**	Are there sufficient gaps between buildings to prevent pounding?
-			Are there sufficient gaps to prevent damage from potentially unsafe structures in an event?
-			Is the site situated a safe distance from hazardous land use that has a high risk of explosion, vulnerability to fire or chemicals?
3.8	**Site Exposure**	**Mitigation Measures - Comms / Access**	Does the site have good quality evacuation routes/roads?
			Is there exterior space on site to provide safe refuge?

Building Vulnerability

4.1	**Building vulnerability**	**Construction Methodology**	Frame/Stability system
			W1 - Timber - Light wood frame, residential or commercial, < 5000sqft
			W2 - Timber - Wood frame buildings, > 5000sqft
			S1 - Steel - Steel, moment resisting frame
			S2 - Steel - Steel braced frame
			S3 - Steel - Light metal frame
			S4 - Steel - Steel frame with cast in place concrete shear walls
			S5 - Steel - Steel frame with unreinforced masonry infill
			C1 - Concrete - Concrete moment resisting frame
			C2 - Concrete - Concrete shear wall
			C3 - Concrete - concrete frame with unreinforced masonry infill
			PC1 - Pre cast concrete - Tilt-up construction
			PC2 - Pre cast concrete - Precast concrete frame
			RM1 - Masonry- Reinforced masonry with flexible floor and roof diaphragms
			RM2 - Masonry - Reinforced masonry with rigid diaphragms
			URM - Masonry - Unreinforced masonry bearing wall buildings
			Façade system description
			Floor system description
			Stair system description
			Roof system description
4.2	**Building vulnerability**	**Building Configuration**	Sketch plan
			Sketch elevation
			Plan characteristics:
			Re-entrant corners
			Enclosed courtyard
			Asymmetric
			Indirect lateral load path
			Columns or load bearing walls irregularly distributed
			Other
			Elevation characteristics:
			Soft story
			The ground floor of the building is elevated significantly above surrounding ground level
			Ground floor at or below immediate external floor level
			Building threshold at or below immediate external floor level
			Indirect vertical load path - Column or load bearing wall locations vary between floors
			Cantilevers
			Set backs at upper stories

			Foundations at different levels
			Higher weights in upper floors
			Random opening pattern in façade
			Other
			Other characteristics:
			Large roof overhangs
			Flat or shallow roof
			Long span roof structures
			Stability system is eccentric to center of mass
			Other
4.3	**Building vulnerability**	**Structural capacity**	Foundation type (state source of information and state material if known)
			Pads
			Strips
			Raft
			Piles
			Mixed
			Soil type (reference source)
			A - Hard rock
			B - Average rock
			C - Dense soil
			D - Stiff soil
			E - Soft soil
			F - Poor soil
			Foundations issues if known
			Vertical element (wall/column) not supported by a foundation
			Foundations not tied together
			Other
			Lateral load system issues
			Building stability system is not evident in one direction
			Building stability system is not evident in either direction
			Walls are not well tied at top/bottom
			Floors are not well tied to walls/columns
			Large openings in floors
			Lack of redundancy in stability system
			Other
			Vertical load system issues
			Horizontal structural members not securely connected to walls/ columns
			Large openings in load bearing walls
			Slender columns
			Short columns
			Walls/ columns more than one story height
			Strong beams weak columns

			Other
			Roof issues
			Roof structure at irregular spacings
			Roof connections have not been engineered
			Roof is not well tied to tops of walls/columns
			Other
			Floor issues
			Floor structure at irregular spacings
			Floor connections have not been engineered
			Floor is not well tied to tops of walls/columns
			Other
4.4	**Building vulnerability**	**Structural deterioration**	Structural deterioration
			Evidence of foundation settlement
			Signs of deflection or sagging in roof or floors
			Erosion at base of building/ exposure of foundations
			Signs of cracking
			Evidence of corrosion
			Evidence of spalling (plaster/ concrete/ masonry)
			Evidence of damage to mortar joints
			Signs of water ingress/ water damage
			Evidence of damage to elements from previous disasters
			Timber deterioration
			Other signs of deterioration
4.5	**Building vulnerability**	**Non-structural elements**	What materials are the furniture fixtures and fittings made of?
			Wood
			Metal
			Plastic
			Other
			Building envelope observations:
			Masonry veneer on exterior walls
			Precast façade units
			Metal/ glass curtain wall
			External non-load bearing walls
			Heavy roof covering
			Aggregate surface roof covering or lightweight pavers
			Light weight roof covering
			Brittle roof covering
			Non-impact resistant glazing
			Protection to windows e.g. shutters
			Large window openings in walls
			Other

			Internal Fit-out observations
			Lightweight wall partitions
			Block / hollow clay tile partitions (unreinforced)
			Gypsum Board Partitions
			Partition walls that terminate at ceiling
			Unreinforced Concrete Masonry Units / Hollow clay tile around exit ways
			Heavy plaster suspended ceilings
			Suspended Ceilings
			Other
			Other elements
			Unreinforced masonry parapet (slender)
			Balconies
			Unreinforced chimneys
			Non-impact resistant glazing above egress routes
			Exterior entrance canopies/ covered walkways
			Externally mounted signage
			Heavy lockers, library shelves, vertical filing cabinets not anchored to structure
			Boundary wall
			Other
			Plant equipment and other services
			Externally mounted mechanical systems
			Heavy roof mounted equipment
			No Flexible connections for gas pipelines
			No Fire extinguishers and buckets accessible
			No Backup fire alarm system
			Hazardous materials not protected
			Potable water systems not protected
			Utility distributions systems inadequately braced and supported
			Other

Appendix E

School Construction Typology

E1 Schools sorted by Construction Typology

E1.1 Pre 1950 Un-reinforced Masonry

School Name	
Location	Sukhbaatar District
Year	1940
Funding	Soviet/ Mongolian State
Building design origin	Soviet Design
Stories	4 + basement
Construction Type	Loadbearing unreinforced masonry
Floor type	Timber
Survey?	RVA

E1.2 Pre 1950 Timber

School Name	
Location	Chingeltai District
Year	Unknown
Funding	Soviet/ Mongolian State
Building design origin	Unknown
Stories	1
Construction Type	Timber
Floor type	Timber
Survey?	RVA

E1.3 Pre 1975 Soviet Model Unreinforced Masonry

School Name	
Location	Songinokhairkhan
Year	1958
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 1
Stories	2
Construction Type	Loadbearing unreinforced masonry
Floor type	Unknown
Survey?	Demolished

School Name	
Location	Songinokhairkhan district
Year	1963
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 1
Stories	2
Construction Type	Loadbearing unreinforced masonry
Floor type	Timber
Survey?	RVA

School Name	
	Khanuul District
Year	1969
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model School - 1
Stories	3
Construction Type	Loadbearing unreinforced masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	
Location	Nalaikh District
Year	1973
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model School - 1
Stories	3
Construction Type	Loadbearing unreinforced masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	
Location	Khanuul District
Year	1976
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 2
Stories	1
Construction Type	Loadbearing unreinforced masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

E1.4 Pre 1990 Soviet Model Reinforced Masonry

School Name	
Location	Khanuul District
Year	1982
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 3
Stories	2 + basement
Construction Type	Reinforced masonry with RC beams at each floor
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	
Location	Unknown
Year	1982
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 3
Stories	2
Construction Type	Reinforced masonry with RC beams at each floor
Floor type	Precast RC hollowcore plank
Survey?	External visit

School Name	
Location	Unknown
Year	Unknown
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model Kindergarten - 3
Stories	2
Construction Type	Reinforced masonry with RC beams at each floor
Floor type	Precast RC hollowcore plank
Survey?	External visit

School Name	
Location	Sukhbaatar District
Year	1984
Funding	Soviet/ Mongolian State
Building design origin	Soviet Design (See Notes)
Stories	3
Construction Type	Reinforced Masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	
Location	Khan-Uul
Year	1987
Funding	Soviet/ Mongolian State
Building design origin	Soviet Model School - 2
Stories	3 (including 1 additional)
Construction Type	Reinforced masonry with RC beams at each floor
Floor type	Precast RC hollowcore plank
Survey?	External visit

E1.5 Donor funded Reinforced Masonry

School Name	
Location	Sukhbaatar District
Year	2004
Funding	World Vision
Building design origin	Baldans (Mongolian Consultant)
Stories	2 + basement
Construction Type	Reinforced masonry with RC beams at each floor
Floor type	Precast RC hollowcore plank
Survey?	Full

E1.6 Donor funded RC Frame

School Name	
Location	Bayanzurkh District
Year	2001
Funding	JICA
Building design origin	Yokogawa Architects and Engineering Inc. Mohri Architects (Manila)
Stories	3 + basement
Construction Type	RC frame with non structural masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	

Location	Chingeltai District
Year	2006
Funding	JICA
Building design origin	MOHRI Architects, Manila
Stories	4 + basement
Construction Type	RC frame with non-structural masonry
Floor type	Precast RC hollowcore plank
Survey?	RVA

School Name	
Location	Bayanzurkh District
Year	2008
Funding	World Vision and Government
Building design origin	Unknown
Stories	3
Construction Type	RC frame with non-structural masonry
Floor type	RC (type unknown)
Survey?	Visited with world vision

E1.7 Donor Funded Timber Frame

School Name	
Location	Songinokhairkhan District
Year	2013
Funding	World Bank
Building design origin	Unknown - 'Canadian Timber Technology' (See Notes)
Stories	2
Construction Type	Timber
Floor type	Timber
Survey?	RVA

E1.8 MoES Model School

School Name	
Location	Songinokhairkhan District
Year	2015
Funding	MoES
Building design origin	MoES Model KG Design - Baldans (Mongolian Consultant) and RC detailing by GIX (Mongolian Consultant)
Stories	2
Construction Type	RC frame with non-structural masonry
Floor type	Cast in place RC slab
Survey?	Visit

E1.9 Notes

Canadian Timber Technology refers to insulated timber clad timber framed buildings. The building code was updated in 2006 to accommodate this kind of construction. The code was borrowed from Canada.

One design was sufficiently different to other 'Soviet Model' designs to suggest it may have been a one off design. Given the small sample size it is possible however that this is another type of 'Model School' design.

E1.10 Caveats

The following caveats affecting the surveys are noted:

- Internal bonding patterns for thick masonry walls are unknown. This can have a significant impact on structural behavior during a seismic event.
- Design drawings and other documents presented were mostly in Russian or Mongolian.
- Schools are generally finished to a high level with raised timber floors, tiling, suspended ceiling panels and thick plaster meaning the structural fabric could not often be seen. Maintenance budgets are about enough to ensure relatively regular re-plastering and re-painting meaning that defects can be obscured.
- On only one occasion was it possible to inspect a roof void.

E2 Typology Summary

Category	Construction Typology		Structure	Floor	Dates (Approx)	Stories
Pre 1975	1	Pre 1950 Unreinforced Masonry	Loadbearing unreinforced masonry	Timber	Pre 1950	4
	2	Pre 1950 Timber	Timber	Timber	Pre 1950	1
	3	Pre 1975 Unreinforced Masonry	Loadbearing unreinforced masonry	Precast RC hollowcore plank	1950 - 1975	1 - 3
1975 - 1990	4	Pre 1990 Reinforced Masonry	Reinforced masonry with RC beams at each floor	Precast RC hollowcore plank	1975 - 1990	2 - 3
1990 - 2014	5	Donor funded Reinforced Masonry	Reinforced masonry with RC beams at each floor	Precast RC hollowcore plank	1990 - 2014	2
	6	Donor funded RC frame	RC frame with non-structural masonry	Precast RC hollowcore plank	1990 - 2014	3 - 4
	7	Donor funded Timber Frame	Timber	Timber	2006 - 2014	2
2014 -	8	MoES Model School	RC frame with non-structural masonry	Cast in place RC	2014 -	2

Appendix F

Key Dates

F1 Key Dates

Construction Typologies of schools in UB City can be seen to be primarily dictated by chronology. The following table is a full list of dates of key events affecting Construction Typology

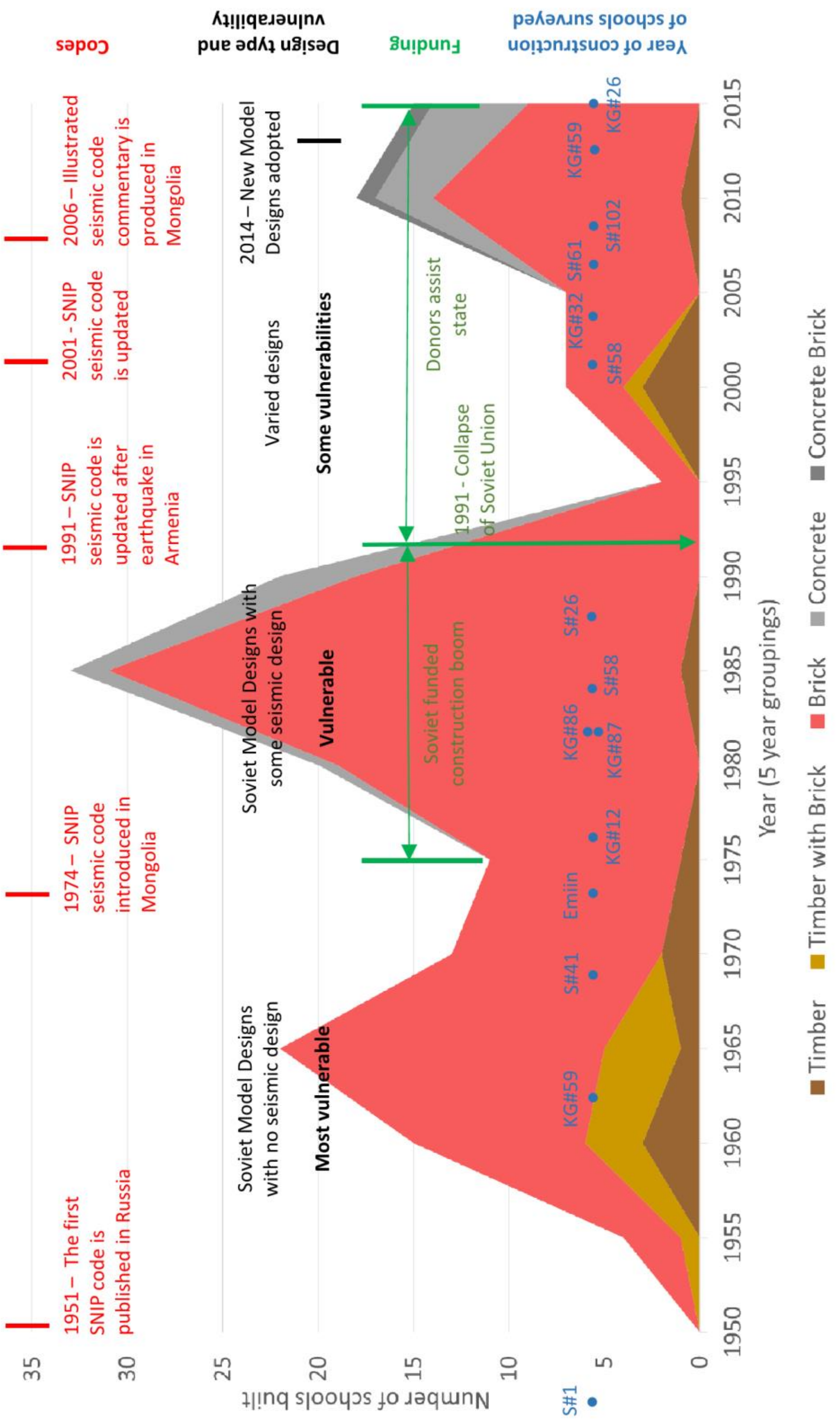
Year	Codes	Other
1951	SNIP (Soviet Union) Code Issued in Russia - Regulations on Construction in Seismic Regions, PSP 101-51 Mongolia adopted Russian Codes as they were issued. When exactly this practice started in unclear but was in place by the 60s.	
1952		
1953		
1954		
1955		
1956		
1957	SNIP Code issued in Russia - Regulations on Construction in Seismic Regions, SN 8-57	
1958		
1959		
1960		
1961		
1962	SNIP Code issued in Russia - Construction in seismic regions, SNIP II-A.12-62	
1963		
1964		
1965		
1966		Flood - Water level in River Tuul rose 3.12m, 130 people died and 7.4million USD of damage caused
1967		
1968		
1969	SNIP Code issued in Russia - Construction in seismic regions, SNiP II-A.12-69 SNIP codes area adopted in Mongolia	
1970		Construction methodology improves and includes assessment of seismic hazard
1971		
1972		
1973		
1974	Seismic SNIP codes are adopted in Mongolia	
1975		
1976		

1977		
1978		
1979	Russian school design development norm is adpoted in Mongolia.	
1980		Rapid urbanization happened in the later 60s and peaking in the late 80s (BOLD)
1981	SNIP Code Issued in Russia - Construction in seismic regions, SNiP II-7-81	
1982		Flood - Flash flooding along 42 ephemeral beds and small rivers killing tens of people
1983		
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991	SNIP code issued in Russia - Construction in seismic regions, SNiP II-7-81, following earthquake in Armenia.	Collapse of Soviet Union
1992		
1993		
1994		
1995		
1996		Between 1996 and 2005 18 separate flash floods caused property damage and killed 56 in Bayangol district
1997		
1998	SNIP is partially translated into Mongolian for the first time. The main document remained in Russian but Mongolian specific provisions were produced in Mongol.	Small earthquake felt in Mongolia
1999		
2000		Regulation passed requiring certification of existing buildings by CDC (In response to earthquake in China).
2001	SNIP Code issued in Russia - Construction in seismic regions, SNiP II-7-81	
2002		
2003		Flood - 10 died, 2km of paved roads and 30 shelters destroyed
2004		
2005		Between 1996 and 2005 18 separate flash floods caused property damage and killed 56 in Bayangol district

2006	CDC publishes an illustrated commentary for the Seismic Code in Mongolian. This includes typical details. Timber houses up to 3 storiess are introduced in to the code, based upon Canadian Building Code.	Small earthquake felt in Mongolia
2007		
2008	Seismic design is introduced in technical schools and universities	
2009		Flood - 24 died, hundreds made homeless
2010		NEMA program for the prevention/reduction of earthquake disaster risk is set up
2011	1979 Russian school design development Norm is translated into Mongolian.	
2012		CDC Validation division is set up
2013		
2014		CDC Building clients division is expanded to represent 4 ministries. Their key mandate is to inspect buildings under construction on their behalf. Model school designs were adopted by the MoES

F2 Typology Timeline Chart

The following chart gives an overview of school construction over the last 60 years



Appendix G

School Vulnerabilities

G1 Design

Figure G1.1 - Double height gym - with large openings with loosely fastened timber shutters on one side. Opening size reduced by infilling windows on other side after construction resulting in no bond between old and new masonry.

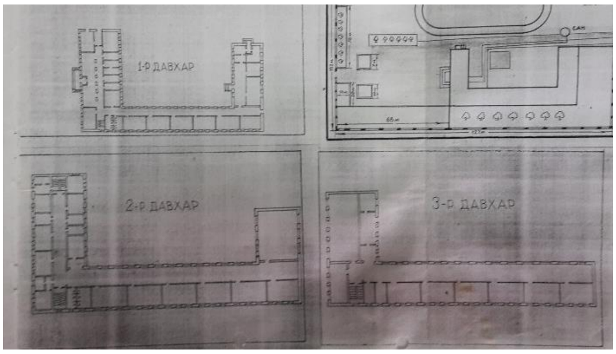


Figure G1.2 - Internal walls - are continuous for classroom block along the bottom of the page but vary between floors for left hand block, with several discontinuing above entrance hall.

Figure G1.3 - New building - built immediately adjoining to existing with seemingly no consideration to seismic movement joints.

Figure G1.4 - Additional story - added to Model Soviet School design.

Figure G1.4 - Movement joints - Soviet model schools typically consist of C or E shaped plans with non-seismic expansion joints dividing them into rectangular segments.

Figure G1.5 - Precast plank - joint made clearly visible by damage caused to plaster via moisture ingress

Figure G1.7 - Heavy weight covered entrance way – are potentially vulnerable in an earthquake.

Figure G1.8 - Suspended ceiling panels - loosely connected back to building fabric are also potentially vulnerable in an earthquake.

G2 Materials, Workmanship and Construction

Figure G2.1 - Masonry bonding - Poorly bonded outer masonry course. Vertical mortar joints align over 3 courses.

Figure G2.2 - Brick types - Yellow bricks with vertical holes susceptible to end damage

Figure G2.3 - Brick types and bonding - Damaged brickwork around window showing red brick masonry behind external yellow brick leaf. Yellow brick leaf is bonded back into red brick masonry every 4th course.

G3 Deterioration

Figure G3.1 - Masonry deterioration - damaged bricks and base of wall undermined.

Figure G3.2 - Cracking in walls - consistent with foundation movement. Possibly due to frost heave and or subsequent settlement.

Figure G3.3 - External water damage - to wall (and foundations) caused by roof gutter terminating several meters above ground. No site drainage.

Figure G3.4 - Internal water damage -associated with leaking roofs and or burst water pipes.

G4 Non-structural vulnerabilities

Suspended ceilings poorly attached to the building fabric are a potential falling hazard, albeit a relatively lesser one compared to vulnerability of floors generally.

Replacement of windows was a common event for older buildings with single glazing, as well as newer buildings with glazing units ill-suited to the extreme weather.

Leaking roofs are common whilst heating systems in older buildings are regularly seen to leak, causing internal damage to the building fabric.

Site wide drainage systems were lacking from every school that was visited. Rain management was frequently seen to be a cause of structural deterioration with leaking roofs and resulting water damage to ceilings and upper walls a common complaint. Roof gutter down pipes were very often seen to terminate several meters above ground, with water damage to the wall and foundations below evident.