



REBUILDING SCHOOLS AND HOMES IN PAKISTAN USING BLOCK TECHNOLOGY: AN EX-ANTE COST-BENEFIT ANALYSIS

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Executive Summary

The devastating floods that struck Pakistan in 2022 have generated substantial human suffering and infrastructure loss. An estimated 33 million people have been affected with 1,700 lives lost. 780,000 homes and 6,255 schools require rebuilding. Fast, resilient, and cost-efficient reconstruction efforts are required to ameliorate the substantial impacts of this and future disasters. Learning losses are particularly important, as losses from poor schooling environments have impacts over the entire working life of each child. **Our analysis indicates that for every year in which children in the 6,255 destroyed schools continue to learn in makeshift facilities or not learn at all, the costs to the future Pakistani economy in lost productivity range from \$240 million to \$1 billion annually.**

This report aims to assist in reconstruction policy by providing an *ex-ante* comparative cost-benefit analysis of rebuilding destroyed schools and homes across three different types of materials: brick and mud (*katcha*), brick and mortar (*pucca*) and a novel plastic recycling technology. This block technology, made from recycled plastic with or without organic material, is lighter and easier to assemble than traditional brick and mortar, making faster reconstruction efforts more feasible.

The results of our analysis indicate that rebuilding schools **using plastic recycled technology returns \$12 for every \$1 spent**, relative to a scenario of 100% *katcha* reconstruction. Using this technology would allow for ~4,500 schools to be built in six years, providing improved learning environments for 360,000 children. Learning benefits are estimated at \$343 million, improved resilience benefits at \$193 million and environmental benefits from recycling plastic at \$8 million, leading to overall benefits of \$544 million. With an incremental cost of \$45 million, the benefit-cost ratio (BCR) of building with blocks is 12. **In comparison, the returns from building using brick and mortar are estimated at 10.7**, entirely driven by a slower reconstruction that is only able to provide 3,900 improved schools in six years.

For homes, the results indicate that rebuilding using block technology yields a BCR of 1.3, compared to 1.1 for brick and mortar. The benefits are improved comfort and shelter (\$2,723 million), improved resilience (\$1,134 million) and environmental benefits from recycled plastic (\$624 million). The marginal cost is estimated at \$3,506 million, leading to a BCR of 1.3.

The main policy implication of the report is that reconstruction efforts need to appropriately balance speed of reconstruction and building quality. The faster Pakistan can rebuild lost infrastructure, the lower the costs of displacement. However, rapid rebuild using sub-optimal, non-resilient materials merely delays the need for action to the not-too-distant future. With climate change and an increasing population, disasters are only going to become more costly. The results of this analysis point towards a potential way in which decision makers could quickly provide resilient and high-quality structures.

1. Introduction

Over the course of the 2022 monsoon season, the Sindh and Balochistan regions of Pakistan experienced six to seven times greater rainfall than historical averages. These unprecedented levels of rainfall, exacerbated by climate change, deforestation and suboptimal land use planning, led to one of the worst natural disasters in the nation's history. An estimated 33 million people have been affected, the most impactful flooding in both absolute and relative scales since 1960. More than 1,700 people were killed (Government of Pakistan *et al.*, 2022).

The floods have caused widespread infrastructure loss. The Post Disaster Needs Assessment Report co-authored by the government and multilateral institutions, estimates that 17,205 schools have been damaged, with 6,255 of them requiring complete rebuild (Government of Pakistan *et al.*, 2022). More than two million houses have been affected, with an estimated 780,000 needing to be reconstructed. This displacement has had profound social and economic consequences. Two million children have had their schooling impacted. Our analysis indicates that for every year in which children in the 6,255 destroyed schools continue to learn in makeshift facilities or not learn at all, the costs to the future Pakistani economy in lost productivity range from \$240 million to \$1 billion annually. Millions have been forced to find temporary shelter and cannot partake in normal livelihood activities. As a result, the national poverty rate is expected to increase by as much as 4 percentage points (Government of Pakistan *et al.*, 2022).

Fast, resilient, and cost-efficient reconstruction efforts are required to ameliorate the substantial impacts of this and future disasters. However, there is a trade-off faced by decision makers. The fastest and least costly material for reconstruction efforts is mud and unbaked bricks, known as *katcha*. It is likely that building with *katcha* would allow communities to return to normal in a relatively short space of time, ameliorating displacement effects. However, these materials are much less resilient to future disasters compared to alternatives. Moreover, building with *katcha* provides less optimal schooling and home environments.

As an alternative, brick and mortar (*pucca*) is more resilient and is generally more desirable from a shelter and learning standpoint. However, brick and mortar are substantially more costly building materials, requiring longer construction times. This means that communities will take longer to return to normal. Recent experience has revealed the challenges of fully rebuilding from flood and earthquake disasters in Pakistan. For example, journalistic accounts have noted that after the 2005 earthquake in Kashmir, less than half of the 7,500 schools were rebuilt after 12 years (Naviwala, 2017). Another account notes that an individual took eight years to rebuild his home after the 2010 floods, due to lack of funds (The Tribune, 2022).

This report introduces a third option, a novel block technology developed by the Finnish company, Block Solutions. The technology is a light weight, plastic-organic composite block that has several advantages over alternative materials such as brick and mud and, brick and mortar. At 10% of the weight of traditional bricks, the recycled plastic blocks can be transported and manipulated more easily, reducing build times and cost compared to *pucca* reconstruction. Moreover, a journalistic account notes that 80% of brick kilns in the Sindh region are inoperable due to the floods, and transport is difficult given road blockages (The Tribune, 2022). To the extent that the recycled plastic blocks can mitigate these challenges (e.g. recycled plastic blocks can be transported more easily), reconstruction could plausibly be faster using the recycled technology. Real-world implementation of homes and schools demonstrate that construction can take as little as 1-3 weeks (see Section 2). At the same time, the block technology has the same resilience, learning and comfort benefits as brick and mortar.



Given the trade-offs, which of these materials should decision makers consider in a rebuild? This report aims to answer this question by conducting an *ex-ante* comparative cost-benefit analysis of rebuilding destroyed schools and homes across all three options. The cost-benefit analysis defines the two intervention scenarios as i) rebuild using recycled plastic blocks and ii) rebuild using brick and mortar. These are compared to a baseline scenario of rebuild using brick and mud. The analysis considers dedicated programs to rebuild the 6,255 schools and the 780,000 homes that were destroyed during the floods.¹ In the baseline scenario, it is assumed all schools and homes can be rebuilt within six and ten years respectively using *katcha*, which is the cheapest material and typically requires the shortest construction time. In the intervention scenarios, only a fraction of the schools and homes can be rebuilt with improved materials (i.e. brick and mortar, or recycled plastic blocks) over six years, after which, communities can no longer wait and remaining homes and schools are built using *katcha*. Key to the reconstruction efforts, the recycled plastic blocks allow for faster reconstruction than brick and mortar because they are lightweight, modular and require less funding per structure.

The results of our analysis indicate that rebuilding schools using block technology returns \$12 for every \$1 spent, relative to a scenario of 100% *katcha* reconstruction. Using this technology would allow for ~4,500 schools to be built in six years, providing improved learning environments for 360,000 children. Learning benefits are estimated at \$343 million, net present value (NPV) using a 5% discount rate. Improved resilience also yields substantial benefits, partially mitigating the roughly 1-in-12 annual risk of experiencing a significant flood. These resilience benefits are estimated at \$193 million in NPV terms. There are also modest environmental benefits from recycling plastic, leading to overall benefits of \$544 million. Relative to an incremental cost of \$45 million, the benefit-cost ratio (BCR) of building with plastic recycling blocks is 12. In comparison, the returns from building using brick and mortar are estimated at 10.7, entirely driven by a slower reconstruction that is only able to provide 3,900 improved schools in six years.

For homes, the results indicate that rebuilding using block technology yields a BCR of 1.3, compared to 1.1 for brick and mortar. In the main analysis, we assume 409,000 homes can be rebuilt in six years using the block technology compared to only 351,000 homes using brick and mortar. The benefits are improved comfort and shelter (\$2,723 million), improved resilience (\$1,134 million) and environmental benefits from recycled plastic (\$624 million). The marginal cost is estimated at \$3,506 million, leading to a BCR of 1.3. For both schools and homes, sensitivity analyses that consider alternative assumptions confirm the broad findings. However, school BCRs are more sensitive to changes in assumptions.

The main policy implication of the report is that reconstruction efforts need to appropriately balance speed of reconstruction and building quality. The faster Pakistan can rebuild lost infrastructure, the lower the costs of displacement. Learning losses are particularly important, as impacts from poor schooling environments have impacts over the entire working life of each child. However, rapid rebuild using sub-optimal, non-resilient materials merely delays the need for action to the not-too-distant future. From 1960 to 2022, Pakistan experienced five major floods – an average of one every 12 years. With climate change and an increasing population, disasters are only going to become more costly. The results of this analysis point towards a potential way in which decision makers could quickly provide resilient and high-quality structures.

¹ While substantially more homes and schools were damaged during the floods, these are considered out of scope for this report. Where damage but not complete destruction has occurred, it is likely that these would be repaired using whatever materials the structure was originally built with.

2. Recycled Plastic Blocks Technology

The recycled plastic eco-blocks are based on technology developed by Block Solutions, a Finnish company founded in 2017. The blocks are a bio-composite made from some forms of plastic, in particular polyethylene terephthalate (PET), High-density polyethylene (HDPE) and Polypropylene (PP). The blocks can also include organic wood fibre such as acacia, bamboo, or rice husk.

The blocks are standardized and modular so that structures are easy to assemble and pull apart (Figure 1). There are four different block sizes measuring 100, 200, 400 and 800mm. Each block has a height of 200mm and thickness of 100mm. The blocks are lightweight, weighing approximately one tenth as much as traditional bricks. Lastly, Block Solutions reports that structures made from the blocks are earthquake and water resistant.



Due to these features, construction time can be significantly reduced. In 2021 and 2022, six schools and three homes were built using the technology in Lombok, Indonesia in substantially lower time frames than brick and mortar. Much of the time savings occurs in the construction of the walls, with the blocks designed to fit into each other without the need for mortar. The walls of a typical classroom can be erected in roughly a day.

For example, the first Block Solutions school in the world was constructed in July 2021 in Taman Sari, Lombok, Indonesia. The construction of the three-room school was led by the Australian NGO Classroom of Hope with support from the provincial government. The school was one of 400 schools that had been destroyed, and unrepaired, since a 2018 earthquake struck the island. The walls and roof were erected in 5 days. Including foundations, total build time was three weeks. A timelapse video demonstrating the rapid construction effort can be found online.²

Several homes have also been constructed in Lombok, Indonesia. These homes have typically been 1-2 rooms. Total build time has been reported at seven days, with walls and roofs requiring approximately 2-3 days. A timelapse video of a home reconstruction can be found online.³

² <https://www.youtube.com/watch?v=Z8CVGbSu4hw&lc=UgwGr5XflxoHoXV1-HN4AaABAg>

³ <https://www.youtube.com/watch?v=dQ3Z671weuw>



3. Cost-Benefit Analysis

General Parameters and Scenario Description

Figures in this report are denominated in 2021 USD, the latest year for which most data are available. Reconstruction efforts are assumed to start in 2023. The analysis considers programs separately for schools and homes. In the section on learning benefits, we note that future income is expected to grow at 2.5% per year, reflecting the average real growth rate since 1981. Following Robinson *et al.*, (2019) we adopt a social discount rate of 5%, equivalent to 2x short term expected per income capita growth rate.

The post-disaster needs assessment notes 6,255 schools requiring rebuild (Government of Pakistan *et al.*, 2022). In the baseline scenario, reconstruction is assumed to take six years if *katcha* structures are pursued. For brick and mortar, we assume a slower construction rate, that starts at 782 (12.5% of all schools) and declines slowly to 313 schools (5% of all schools) in 2028. The construction pathway for recycled plastic assumes a slower construction rate initially (5% of all schools), to account for potential learning effects of building with a novel material, but scales rapidly in the years after reflecting the ability to construct faster (Figure 4). By the end of the time horizon (10 years), the analysis assumes:

Baseline, Brick and mud schools:	Intervention, Recycled plastic block schools:	Intervention, Brick and mortar schools:
6,255 schools rebuilt with brick and mud	4,353 schools rebuilt with recycled plastic, the rest with brick and mud	3,909 schools rebuilt with brick and mortar, the rest with brick and mud

With homes, the post-disaster needs assessment notes 780,000 requiring rebuild. In the baseline scenario, reconstruction is assumed to take 10 years using *katcha*. As with schools, brick and mortar homes have a slower reconstruction rate than brick and mud, while recycled plastic blocks roll out is slower still initially and accelerates in the middle years as supply chain is established and builders become familiar with the materials (Figure 5). At the end of year six, any unbuilt homes are gradually built out over the remaining four years using brick and mud. By the end of the time horizon, the scenarios assume:

Baseline, Brick and mud homes:	Intervention, Recycled plastic block homes:	Intervention, Brick and mortar homes:
780,000 homes rebuilt with brick and mud	409,500 homes rebuilt with recycled plastic, the rest with brick and mud	351,000 homes rebuilt with brick and mortar, the rest with brick and mud

It should be noted these are scenarios and not predictions. The scenarios are representations of plausible future states of the world, reflecting stylized differences between the assumed speed of reconstruction. The actual future pathway of reconstruction will depend on a host of unpredictable factors such as availability of funding, governance structures for distributing funds and managing reconstruction efforts, and the resilience of supply chains. Nevertheless, the scenarios, and subsequent cost-benefit analysis provides useful policy insights about the impacts of improved reconstruction.

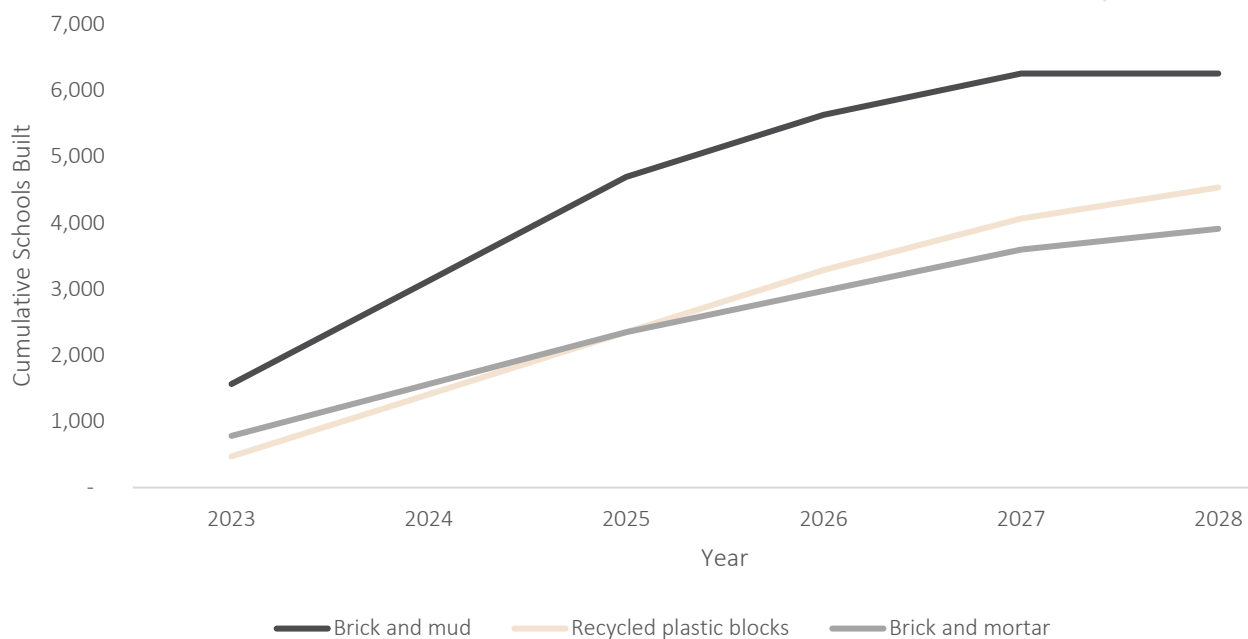


Figure 4: Pathway of school reconstruction

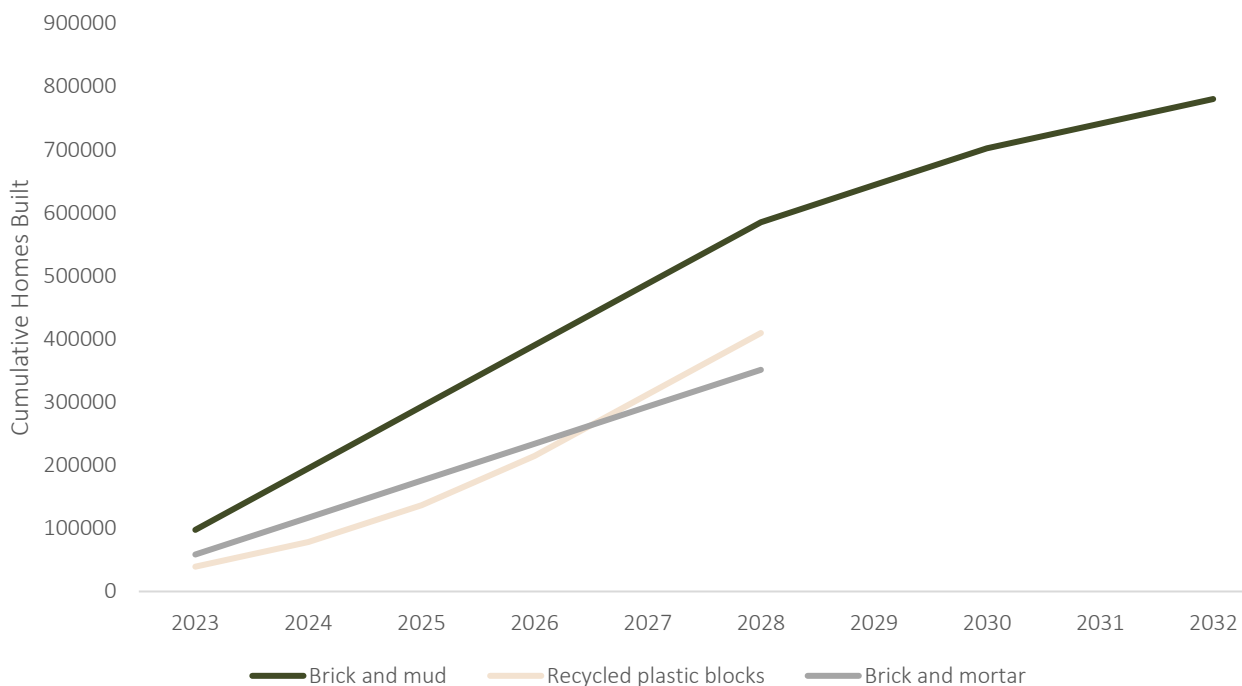


Figure 5: Pathway of home reconstruction, after 2029 in the recycled plastic and brick and mortar scenarios, homes are assumed to be rebuilt using brick and mud until all homes have been complete.

Costs

The costs of the reconstruction were estimated by a combination of on-the-ground data collection and historical experience from rebuild efforts in Indonesia using the recycled plastic blocks. To keep the analysis tractable, we assume each school contains three classrooms of 1,000 sq ft, while each home is assumed to equal 900 sq ft. capable of having 2-4 multi-purpose rooms. Unit cost parameters are detailed in Table 1. Note that the cost of building with recycled plastic in Indonesia was estimated from accounting records at \$17.7 per sq ft, approximately 11% lower than brick and mortar in Pakistan. To remain conservative, we round this up to \$20 per sq ft, equal to the cost of brick-and-mortar construction. In sensitivity analyses, we demonstrate the impacts of altering construction costs.

	Baseline, Brick and mud	Intervention, Recycled plastic blocks	Intervention, Brick and mortar
School and home construction costs	\$7.5 per sq ft Source: Consultation with local stakeholders	\$20 per sq ft Source: Block Solutions records from Indonesia construction	\$20 per sq ft Source: Consultations with local stakeholders; Naviwala, (2017)

Based on these assumptions, and construction pathways outlined previously, we estimate the costs of the interventions relative to baseline. For recycled plastic blocks, the net present value of costs relative to baseline is \$45 million over 10 years. For brick and mortar, it is \$38 million over 10 years.

Benefits

This section documents the different benefits assessed in the analysis. For both schools and homes there are resilience benefits from construction with improved materials and environmental benefits from recycling plastic. For schools there are learning benefits. For homes there are also comfort and shelter benefits from improved materials.

Learning Benefits (Schools only)

Learning benefits require an estimate of future incomes. As a starting point we take 2021 GDP per capita in Pakistan from World Bank Development Indicators at \$1,538 (World Bank, 2021) as a proxy of average income. This value is assumed to experience real growth at 2.5% per annum, the historical real average GDP per capita growth since 1981.

Given that 80% of the schools requiring rebuild are primary schools (Government of Pakistan et al., 2022), we assume that each person benefiting from improved schooling is 8-years old. This is a simplifying assumption but likely biases benefits of schooling downward to the extent that children are on average older than 8-years.⁴ We divide the average income by a factor $(1+\gamma)^n$ where $\gamma=7\%$, the average return to a year of primary schooling (Aslam et al., 2010), and $n = 4$ years, the remaining years in primary school for an average 8-year old in Pakistan. This provides a stream of expected income for the average 8-year Pakistani, who we assume works from ages 15-64. The stream of future income has an NPV of \$27,580 at a 5% discount rate.

⁴ This is because learning benefits are a positive function of expected income and a negative function of years until working age, due to discounting. Older children who have more education and are closer to working age would benefit more from improved schooling.

Schooling environments matter greatly for learning. The recent review by Barrett et al., (2019) notes that characteristics such as appropriate lighting, airflow and temperature, plus design features that optimize the potential for learning influence education outcomes. Importantly in this context, the review also noted the importance of safe buildings for ensuring both children and teachers perform optimally in school. The review cites a range of literature, mostly from developed countries, that reinforces the broad point that physical schooling environments impact learning. For example, Earthman (2004) showed that US children in poorer buildings had 5 to 10 percentile points lower rank in standardized tests compared to children in better buildings.

For low-and-middle income countries, there is evidence demonstrating the importance of improved learning environments for better education outcomes. In an analysis of a school improvement, construction and upgrade program in Burkina Faso, researchers noted that having a higher quality school increased children's test scores in mathematics and language by 0.34 and 0.29 standard deviations of test scores respectively (Levy et al., 2019), impacts that were sustained seven years later (Kazianga et al., 2019). In Niger, schools that were provided with toilet facilities (including separate boys and girls toilets), playgrounds, and a potable water source improved learning levels in mathematics by 0.13 standard deviations, compared to control schools which mostly lacked these facilities (Bagby et al., 2016). In Malawi, Mulera, Ndala and Nyirongo, (2017) note a positive correlation between the permanence of school buildings and pupil's test scores, while supporting research has shown learning outdoors reduces test scores by 0.093 standard deviations and reduces grade retention by 4 percentage points (World Bank, 2010; Dunga, 2013).

No literature was uncovered that would point to the exact magnitude of benefits associated with the situation at hand. For the purposes of this analysis, it is assumed that moving from temporary schooling facilities to schooling in a brick and mud structure raises learning by 0.1 standard deviations in test scores per year, towards the lower end of impacts noted above. Moving from a brick and mud structure to either of the improved schools (recycled plastic blocks or brick and mortar) raises test scores by a further 0.05 standard deviations in test scores. To put these figures into perspective, one year of average schooling in Pakistan raises test scores by 0.4 standard deviations (Aslam et al., 2010). Therefore, the assumed impacts are the equivalent to the learning generated by roughly between one quarter of a standard school year. These effects seem plausible, if imprecisely estimated.

Improved learning benefits are assessed as the difference between intervention and baseline scenarios in expected future incomes, where learning benefits are given by:

$$Learning\ Benefit = \sum_{t=1}^{10} \frac{\sum_i (S_{i,t} * N * Y * \theta_i * \rho)}{(1 + r)^t}$$

In the above $i \in$ (brick and mud, recycled plastic, brick and mortar), $S_{i,t}$ is the number of schools indexed by i , built by year t (where 2023, $t=1$). $N*Y*\theta_i*\rho$ captures the earnings benefit where N is the number of students per school, set at 80, Y is the NPV of future income noted above, θ_i is the standard deviation improvement in test scores relative to temporary schooling (0.1 s.d. for brick and mud; 0.15 for recycled plastic and brick and mortar) and ρ is the return from a 1 s.d. improvement in schooling estimated as 17% by (Aslam et al., 2010). Lastly r is the social discount rate, 5%.

Comfort and Shelter Benefits (Houses only)

Analogous to the idea that building with improved materials lead to improved learning environments in schools, building with improved materials in houses also generates benefits. These benefits are hard to define but broadly reflect the satisfaction of household preferences towards better constructed homes. We call these comfort and shelter benefits.

The theoretically appropriate way to estimate the benefits arising out of construction from improved materials would be to identify the market prices of two otherwise identical houses, one built from *katcha*, the other from improved materials. The difference would represent the comfort and shelter benefits of the improved materials. Such a theoretical scenario does not exist, and so we are forced to find a proxy for market price differences.

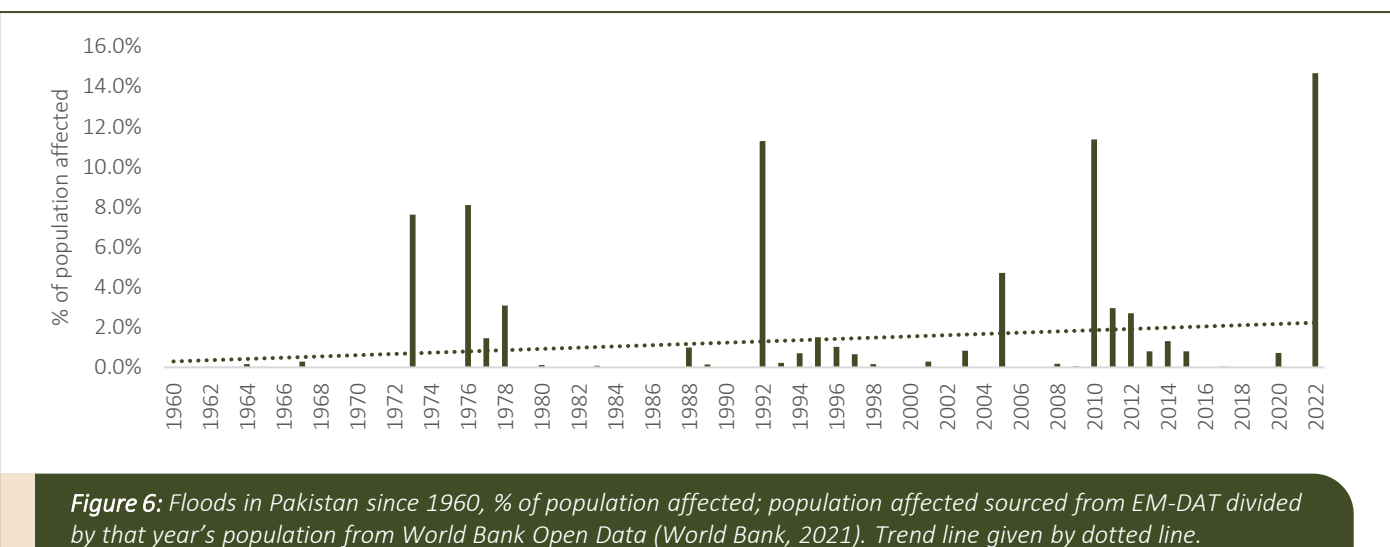
Standard economic theory indicates that in a competitive market, differences in construction costs should somewhat reflect differences in market values. If one material was 50% more expensive to build with but led to houses that were 100% more valuable on the open market, then it would pay to continue construction with that material. This would lead to increased costs of construction as demand rises, until premia reached equilibrium. Therefore, we use the ratio of differences in the construction costs as the value of the comfort and shelter benefits from using the improved materials.

Lastly, we estimate the market price of houses as the construction cost multiplied by the expected return on capital in the housing market in Pakistan (land was not included in the calculation since for a given house, the land is unchanged). Housing price index data was sourced from Zameen over the period 2012-2021 to estimate a return on capital. Adjusted for inflation, the real return on housing capital is 10%.

Compared to a *katcha* house, the comfort and shelter benefits of building with improved materials are therefore equal to \$12,377 per structure.

Resilience Benefits (Homes and Schools)

Brick and mortar, and plastic recycled blocks are expected to be more resilient to damage than *katcha* structures. Pakistan is subject to major flooding on a regular basis. Information from the EM-DAT database indicates that since 1960, there have been five major floods where at least 7.5% of the entire population was affected in Pakistan (Figure 6). All of these major floods have occurred in the regions impacted by the 2022 disaster. The data reflect a chance of major flooding once every 12.4 years. Simple trend analysis shows that the share of population affected by floods has been rising since 1960.

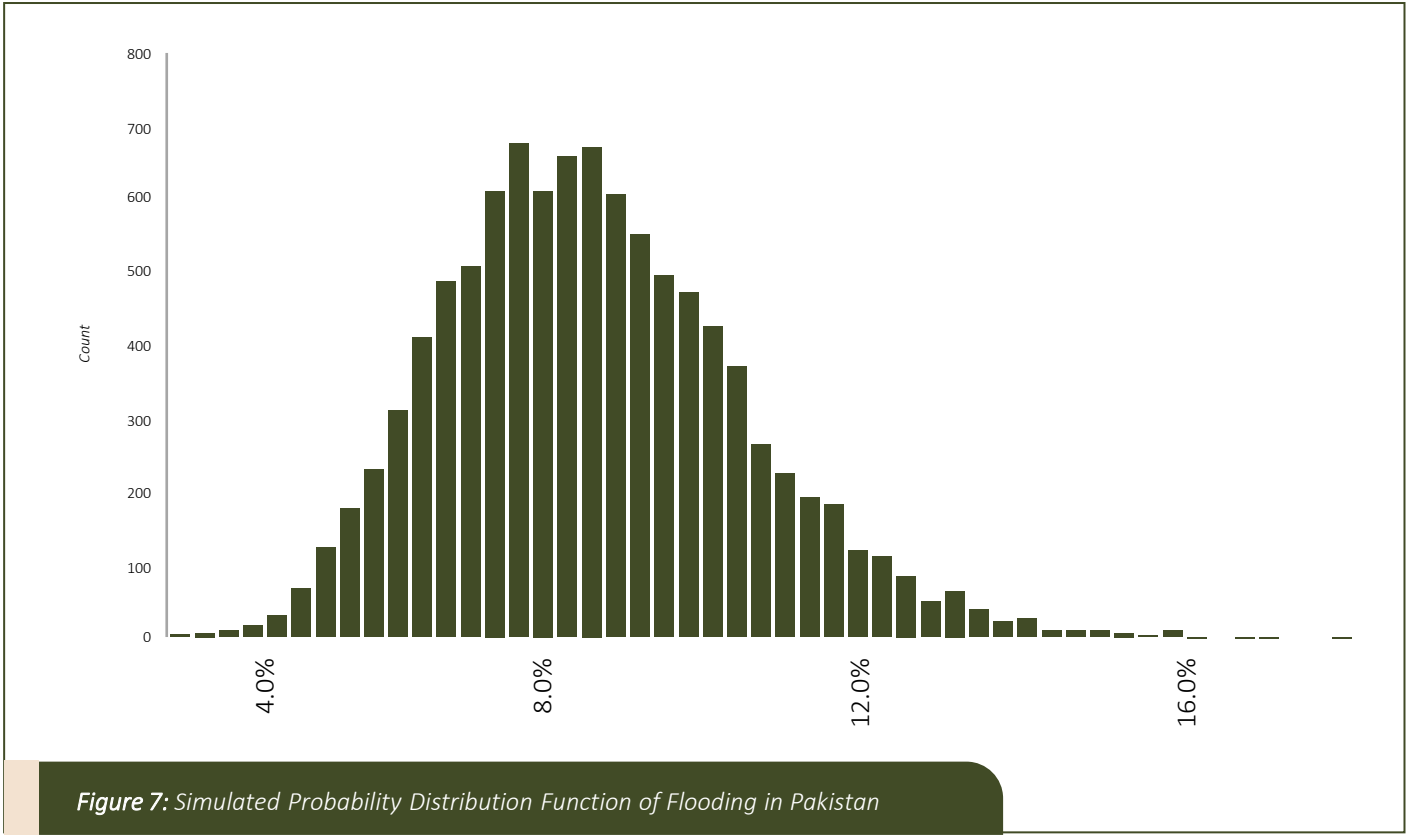


Historical flood data is used to project future flooding intensity. The average historical impact is 1.25% of the population impacted, with a standard deviation of 0.09% per year.

The probability distribution of annual future flood intensity is estimated by a Monte Carlo simulation across 10,000 iterations following a gamma distribution with parameters $\alpha = 17.47$ and $\beta = 0.07$. Since floods have almost always been concentrated in certain regions of the country (i.e. floods do not affect the whole population, just a subset), impact values from the whole-of-country simulation are adjusted upwards to assess true risk of damage for the flood-prone regions where the schools and homes are to be rebuilt.

The results of the simulation (Figure 7) indicate a mean risk of a structure in flood-prone regions being subject to flooding of 8.5% per year. Being in a flood, however, does not mean that the structure will necessarily be destroyed. We use the ratio of structures destroyed to structures affected to estimate the likelihood of destruction conditional on being flood affected. That ratio is 36% for schools and 38% for houses. We further assume that having a superior building material (brick and mortar or recycled plastic blocks) avoids all damage that would lead to a structure being destroyed (requiring full rebuild) but cannot avoid any damage that would lead to a structure being damaged (requiring repair).

The benefit of resilience is the avoided cost of reconstruction for schools and homes, assessed as the value of mud and brick reconstruction. For schools, we also avoid the costs of interrupted learning associated with the floods. Avoided interruption benefits are estimated using the same methodology as for the learning benefits, assuming each school would require 2.5 years to rebuild on average.⁵ The costs of learning interruption (\$95,612) are substantial and represent a cost that is 13x the costs of reconstruction (\$7,500).



⁵ Two and a half years is the approximate weighted average reconstruction time for katcha schools under the baseline scenario.

Note that for homes, the resilience benefits are likely captured in the differing market price of houses. As such, resilience benefits are subtracted from comfort and shelter benefits assessed above, to avoid double counting. The resilience benefit per improved structure is estimated at \$3,372 over the structure's expected life, 30 years.⁶

Note that this benefit does not include avoided damage from other natural disasters, such as earthquakes. To the extent that improved structures would also be resilient to other natural disasters, the benefits are underestimated.

Environmental Benefits (Recycled Plastic Block Schools and Homes only)

Construction using the recycled plastic materials removes plastic from the environment that would otherwise cause harm to the environment and human health. In a previous report for Block Solutions the social cost of plastic was estimated at \$275 per tonne, with a range between \$190 and \$360 (Wong, 2021). This value is applied to this analysis. Each 1,000 sq ft school school is assumed to remove 7.5 tonnes of plastic from the environment, while each 900 sq ft house is assumed to remove 6.75 tonnes of plastic. These figures were provided by Block Solutions and are based on technical specifications of their injection moulding technology.

Results

The results of the analysis for schools are presented in Table 2 and depicted graphically in Figure 8. Under the recycled plastic blocks scenario, total benefits equal \$544 million of which 63% represent learning benefits (\$343 million), 35% represent resilience benefits (193 million) and 1% environmental (\$8 million). Under the brick and mortar led reconstruction scenario, total benefits are \$412 million of which 59% are learning benefits and 41% are resilience benefits.

Incremental costs under recycled plastic blocks led reconstruction are \$45 million, while brick and mortar led reconstruction are \$38 million. The higher costs for the recycled plastic block scenario are entirely because more improved structures can be built using this material, compared to brick and mortar. As noted in Table 1, unit costs are assumed to be equal for these materials.

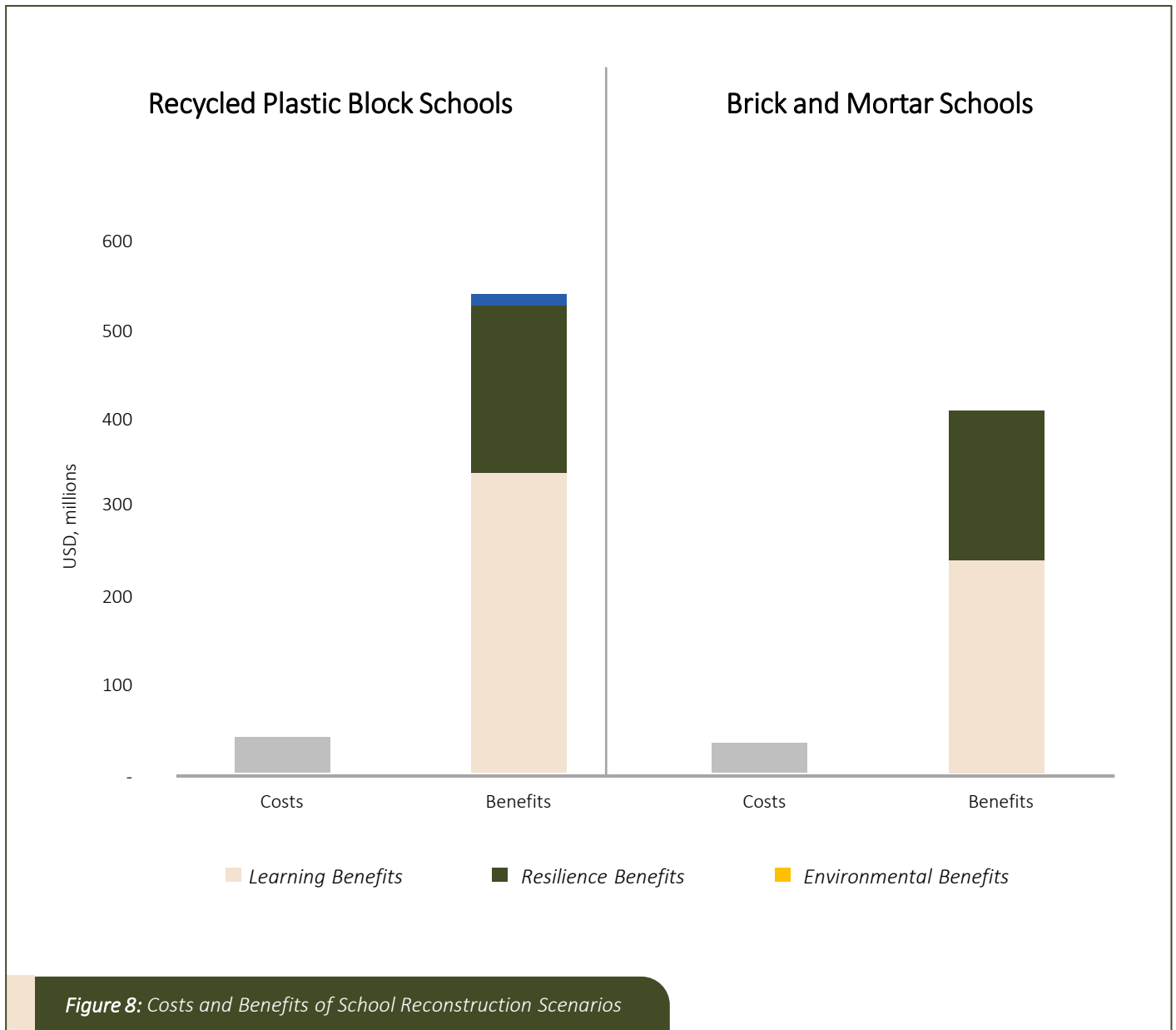
The BCR for recycled plastic blocks is 12.2, while for brick and mortar led reconstruction it is 10.7.

Table 2: Incremental Benefits and Costs, BCRs of School Reconstruction Scenarios

SCHOOLS (n=6,225)	Recycled plastic blocks led reconstruction	Brick and mortar led reconstruction
Learning Benefits (millions, USD)	343	243
Resilience Benefits (millions, USD)	193	170
Environmental Benefits (millions, USD)	8	-
Total Incremental Benefits (millions, USD)	544	413
Total Incremental Costs (millions, USD)	45	38
Benefit-Cost Ratio (Benefits / Costs)	12.2	10.7

Costs and Benefits estimated relative to a baseline scenario of brick and mud led reconstruction. Reconstruction pathways and methodology for estimating costs and benefits noted in text. All figures reported in 2021 USD and assuming a 5% social discount rate.

⁶ Recycled plastic structures have been technically assessed at a useful life of 100 years. To remain conservative, we assume 30 years for both recycled plastic and brick and mortar.



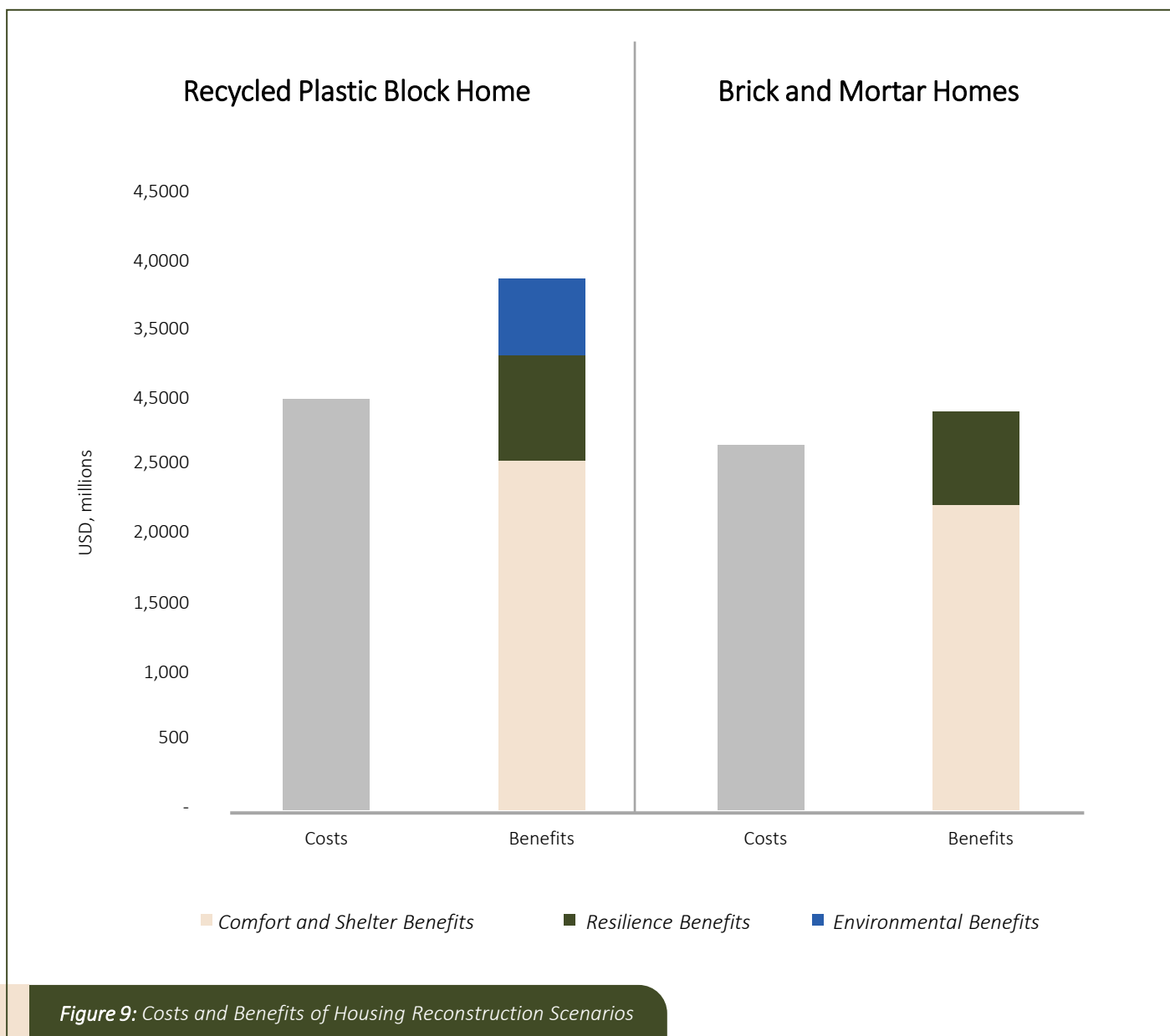
The results of the analysis for houses are presented in Table 3 and depicted graphically in Figure 9. Under the recycled plastic blocks scenario, total benefits equal \$4,481 million of which 61% represent comfort and shelter benefits (\$2,723 million), 25% represent resilience benefits (1,134 million) and 14% environmental benefits (\$624 million). Under the brick and mortar led reconstruction scenario, total benefits are \$3,366 million of which 70% are comfort and shelter benefits and 30% are resilience benefits.

Incremental costs under recycled plastic blocks led reconstruction are \$3,506 million, while brick and mortar led reconstruction are \$3,059 million. The BCR for recycled plastic block housing is 1.3, while for brick and mortar led reconstruction it is 1.1.

Table 3: Incremental Benefits and Costs, BCRs for Housing Reconstruction Scenarios

HOUSES (n=780,000)	Recycled plastic blocks led reconstruction	Brick and mortar led reconstruction
Comfort and shelter Benefits (millions, USD)	2,723	2,354
Resilience Benefits (millions, USD)	1,134	1,012
Environmental Benefits (millions, USD)	624	-
Total Incremental Benefits	4,481	3,366
Total Incremental Costs	3,506	3,059
Benefit-Cost Ratio (Benefits / Costs)	1.3	1.1

Costs and Benefits estimated relative to a baseline scenario of brick and mud led reconstruction. Reconstruction pathways and methodology for estimating costs and benefits noted in text. All figures reported in 2021 USD and assuming a 5% social discount rate. Comfort and shelter benefits do not include resilience benefits which have been estimated separately.



Sensitivity Analyses

We conduct a one-way sensitivity analysis by altering several parameters used in the above analysis. The impact of assumptions on school BCRs are presented in Table 4. Variation in discount rates, learning impacts, costs of materials and intervention rebuild speeds appear to impact BCRs substantially. However, there appears to larger upside variation than downside, relative to central BCRs. Moreover, in all cases, except one, the BCRs from Recycled Plastic Block led reconstruction are higher than the BCRs for brick and mortar.

Table 4: Sensitivity Analyses, School BCRs

	Recycled Plastic Block Led Reconstruction	Brick and Mortar Led Reconstruction
Speed of rebuild in intervention scenario 25% faster	15.5	14.6
Speed of rebuild in intervention scenario 25% slower	6.1	3.5
Speed of rebuild in baseline scenario, 25% faster	10.2	8.3
Speed of rebuild in baseline scenario, 25% slower	14.6	15.1
Cost of improved materials, 25% higher	8.5	7.5
Cost of improved materials, 25% lower	21.4	19.1
Cost of brick and mud, 25% higher	15.0	13.3
Cost of brick and mud, 25% lower	10.3	9.0
Learning impact from intervention 0.1 SD relative to brick and mud	28.1	27.2
Learning impact from intervention 0.025 SD relative to brick and mud	4.3	2.5
Resilience benefits 50% higher	14.4	12.9
Resilience benefits 50% lower	10.0	8.5
Discount rate 3%	25.0	22.5
Discount rate 8%	5.0	4.2

Table 5: : Sensitivity Analyses, Home BCRs

	Recycled Plastic Block Led Reconstruction	Brick and Mortar Led Reconstruction
Speed of rebuild in intervention scenario 25% faster	1.3	1.1
Speed of rebuild in intervention scenario 25% slower	1.3	1.1
Speed of rebuild in baseline scenario, 25% faster	1.3	1.1
Speed of rebuild in baseline scenario, 25% slower	1.3	1.1
Cost of improved materials, 25% higher	1.2	1.1
Cost of improved materials, 25% lower	1.4	1.1
Cost of brick and mud, 25% higher	1.3	1.1
Cost of brick and mud, 25% lower	1.3	1.1
Comfort and shelter benefits 50% higher	1.3	1.2
Comfort and shelter benefits 50% lower	1.3	1.0
Resilience benefits 50% higher	1.3	1.1
Resilience benefits 50% lower	1.3	1.1
Discount rate 3%	1.3	1.1
Discount rate 8%	1.3	1.1

Results for sensitivity analyses for homes are presented in Table 5. In contrast to schools, BCRs are relatively stable across changes in assumptions. In all cases, the BCRs for recycled plastic blocks are higher than for brick and mortar.

4. Conclusion

This report conducts a benefit-cost analysis of rebuilding schools and homes examining impacts of two different types of materials compared to brick and mud reconstruction. The analysis points to the importance of rebuilding quickly, particularly for schools, where the learning losses are substantial. Overall, the analysis suggests that building with recycled plastic technology is likely to lead to greater benefits, even if unit costs are equivalent to brick and mortar. In the central scenario, the BCR from using recycled plastic block technology for schools is 12.2 compared to 10.7 for brick and mortar. For homes the BCR is 1.3 for recycled plastic and 1.1 for brick and mortar. The higher BCRs are entirely driven by a faster assumed rebuild, which appears feasible given the nature of the materials as lightweight, modular and easily transportable. Conducting demonstration builds using this novel technology, would help to confirm the assumptions used in this report.

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