Exploration Of Human-Centered Mass Customisation and Personalisation Potentials for Flood Shelter Evolution in Australia

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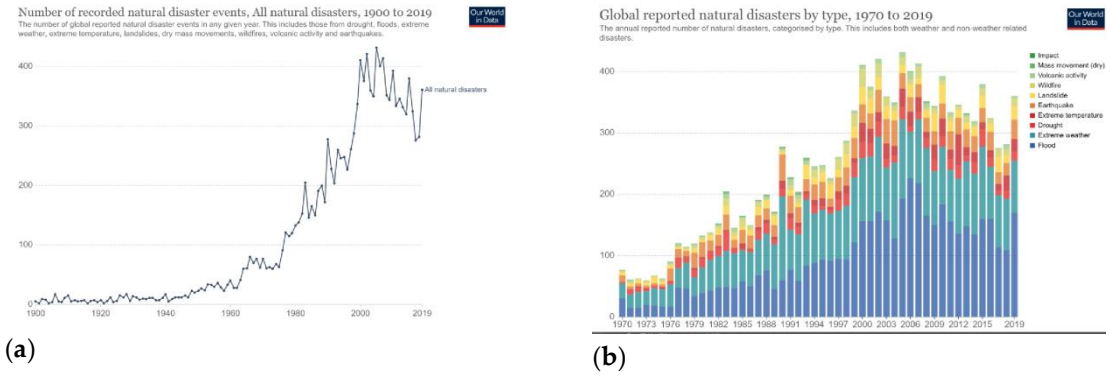
Abstract: Natural disasters have always plagued human life. Due to the global warming caused by frequent occurrence of floods, it has brought immeasurable impacts on politics, economy and human life. The relevant technology and development of post-disaster reconstruction and the physical and psychological humanitarian assistance to the disaster-affected population have been paid more and more attention by the governments and organizations of various countries. At present, with the development of science and technology, mass customisation has been widely used in the construction market. However, there is insufficient theoretical or practical research on post-flood mass customized reconstruction based on the needs and demands of the affected population and buildings. Therefore, this paper will focus on Australia's flood issues and to clarify the lack of "customisability" of today's post-flood shelter to accommodate human needs and demands for health, well-being, inclusiveness and affordability and stress the mass customisation and personalisation potentials to the improvement. Furthermore, this paper will explore a research framework by introducing human-centered mass customization to post-flood housing design under the theoretical research of mass-customisation and occupants' needs and demands. In detail, according to the study of post-flooding issues and current protecting shelter in Australia, a clear housing and occupants' needs and demands could be quantified. Then, deducing a conceivable research framework to emphasize the relationship between human needs with theories of human-centered mass customisation and personalisation based on these advantages in post-disaster housing reconstruction.

Keywords: Post-disaster housing; Flood issues; Mass-customisation; Human centered personalization; Human wellness

1. Introduction

From ancient till now, human and economic losses caused by crustal movement and hydro-meteorological disasters are common, and the scale of losses of these uncontrollable natural disasters is increasing in these years [1]. The data chart (Figure 1) from "Our World Data", could clearly show the amount of disaster event reports and the degree of each type of disasters. Although, with the development of communication technology and media industry, more disaster data can now be transmitted and recorded in the first place, it's obvious to see the amount of disasters has exploded in recent years [2]. These serious disaster trends also make more and more people realize the value and significance of disaster prevention and post-disaster reconstruction [3]. In general, after a natural hazard, architecture plays an important role not only in restore infrastructure coverage but responding to the functional need for comfort and safety of those affected. Both the temporary needs

for immediate shelter, as well as permanent demands for long-term living stability are key elements which are decide whether the post-disaster architecture is successful [4]. In addition, humanitarian support is much more imperative as physical and mental health treatment for people who has affected by disasters. From the IFRC's 2020 World Disasters Report, millions of people living in a standstill situation are not receiving the humanitarian assistance they desperately need [5]. This paper will take humanitarian design as the goal to explore the methods and strategies of Mass customization and personalization housing design for post-disaster reconstruction.



(**a**) (**b**)

Figure 1. Data statistics of disaster issues from Our World Data. (**a**) Number of disaster events in the world from 1900-2019. ; (**b**)Different types of disasters occur in the world from 1979-2019.

In specific, from the key findings of the Australian climate change department, extreme sea-level events of storm surges will escalate coastal inundation risks [6]. This severe issue has been widely concerned by relevant research organizations and practitioners. However, there are still insufficient design considerations in people's need and demand in relevant post-disaster housing or constructions. As a result, many post-disaster reconstruction buildings cannot provide a comfortable and free-living environment for people to use permanently. Improving people's comfort and adaptability from flooding and sea-level rise issues in Australia becomes an important topic in recent years. Considering the background of global warming and extreme changes of environmental atmosphere, mass customization has its value in friendly environmental housing construction for its advantages of affordable and energy cost reduction. "The concept of mass customization coincidentally emerged as a mean to customize end-user products without sacrificing the production efficiency, effectiveness or low cost." [7]. For the condition of post-disaster housing development, it is necessary to efficiently, economically and rapidly restarting the housing and infrastructure coverage. This makes the concept of mass prefabrication or customization useful in the process of post-disaster reconstruction. Furthermore, with the aim of achieving sustainable development, mass customization residential should have the ability of variability and adaptability, which is to fit the demand of changing occupancy patterns from the transition of temporary to permanent [8].

1.1. Flooding issues in Australia

From the report of NCCARF, climate change is a major and urgent global issue. Climate warming means high-risk flood events, and in the 21st century, continuous and frequent severe floods "almost certainly" will occur. This may cause more serious damage to property and the environment. Floods are already the country's most expensive natural disaster [5,6,7]. In Australia, flooding issues are commonly follow by heavy rainfall into the river and possibly appear in central and western New South Wales and Queensland areas. The flood caused by sea level rise up is another condition in coastal area of east and west Australia. One of the heavy flooding record in Australia was in the Lockyer Valley, Ipswich and Brisbane, summer of 2010-2011. The rare flooding has killed 35 people and left more than 200,000 homeless with a direct and indirect loss of up to 6.64billion dollars. In Brisbane, the river peaked at about 4.43 meters height during this flood occured. A large number of houses were destroyed with uncountable vehicles lost and damaged showed in figure 2-(a). The flooding took nearly two weeks for the waters to recede, and the town was already saturated.

Infrastructure, such as water and electricity pipelines and road surfaces, have been damaged to varying degrees, which undoubtedly adds considerable burden to the reconstruction. In March 2021, another flood accident just happened in Hawkesbury, West Sydney. One of the most striking images is Windsor Bridge after the flood, which is submerged by water showed from figure 2-(b).



(**a**)



(**b**)

Figure 2. post-flooding issues in Australia. (**a**) the disruptions of town housing after flood in Theodore of Queensland on January 1, 2011. ; (**b**) flooding water has submerged the Windsor Bridge in West Sydney, March 2011.

1.2. Identification of research gap

According to the United Nations Environmental Protection Organization report, global warming has become a significant trend. Sea level rising caused by warming and subsequent instability of the atmosphere will lead to a large number of flooding disasters [6-7]. Fortunately, the Australian government attaches great importance to the post-disaster administration and specifies the guideline to rapid infrastructure restoration of affected residents. (The National Flood Risk Advisory Group, 2008) However, post-flooded families' wellness cannot be achieved just by short-term shelter repair and subsidy support. From an architectural perspective, it is still a blank space to explore a permanent housing design plan that can continuously meet people's needs over time and withstand the hazards' impacts of climate change [8-9]. In order to realize such a plan, it is necessary to incorporate human-centered and personalised design into the research process of post-disaster housing reconstruction for human wellness. At present, there is not enough relevant research data in this field for post-flood housing reconstruction in Australia or beyond.

Furthermore, mass customization for post-flood housing reconstruction was hardly researched and used in today's post-flood reconstruction projects as a value engineering concept mentioned above. Although mass customization has the advantages of agility and affordability to meet the needs of post-disaster housing reconstruction, the singleness of its results does not meet the complicated functional requirements brought by the long-term living experiences of post-flood occupants. Therefore, to enhance housing quality and to improve human wellness for post-flood issues, the combination of mass customization and human-centered personalized design for post-flood shelter is of self-evident importance as the core value that this paper wants to explore which is showed on figure 3.

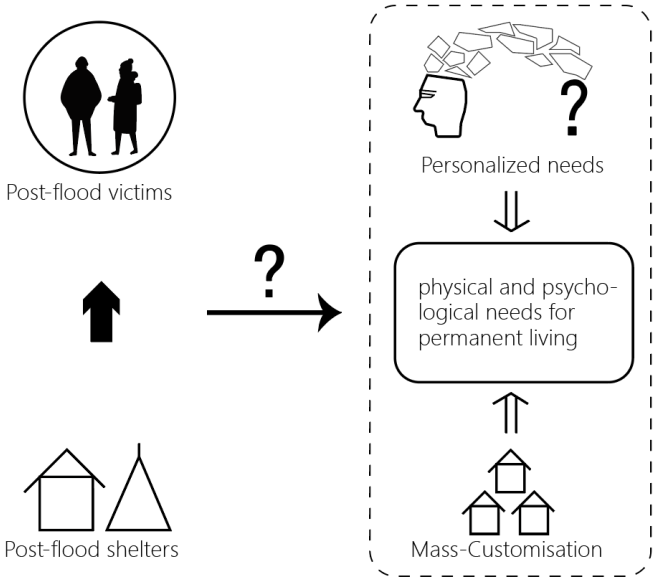


Figure 3. This is a figure shows the diagram of research gap and research aim framework. The analytical diagram was made by author.

2. Literature Review

The literature review summaries supported identification resources focusing on particular research questions under the study field. A literature review is a way to map and access research areas for further research questions or hypothesis justification according to describe previous research[10-11]. This research explores a design solution for post-flood housing reconstruction issues in Sydney, Australia, intending to improve human living experiences by combining theoretical relationship with environmental experience design and mass customisation. Based on the above research purpose and to further design and test the research results, a series of thematic study areas will be selected as detailed research in different stages of the literature review. "Post-flood housing reconstruction and permanent transition, Environmental experience design (EXD), Indoor environmental quality, Human environmental relations, Psychological trauma therapy and human wellness, mass customisation, mass personalisation and so on...

2.1. Occupants' status and needs for post-flood issues in Australia

Post-flood reconstruction as a long-lasting process is often accompanied by consuming a large number of human and financial resources. However, in terms of injury prevention for future disasters, post-flood reconstruction undoubtedly offers an opportunity to increase the stability of resistance. This requires an in-depth study of the potential impacts of natural disasters that may occur to increase the building's adaptability [12]. In order to understand the problems of flood issue, the short-term and long-term impacts for people should be analyzed and judged, respectively. According to the research of short-term impacts by flooding issue, it is easier to find the objective emergent needs for human and infrastructure. From the chart-table 1, office of the Queensland chief scientist, the researchers drew a clear picture of the short-term human and social impacts of flooding, using both tangible and intangible economic costs [12,13].

In short, the short-term chart impacts of flood issue can be summarized as economic and environmental factors. Disruption to transport and the damage of building construction could be seen as economic impacts. The pollution of water and ecological damage will be considered as an environmental factor [14,15]. Though these issue analyses are still in the rough and early stages, it clearly delineates the flexibility, agility, and affordability needs of building materials and design strategies under the requirement of sustainability and environmental protection for post-disaster reconstruction. Hence, from mentioned needs and requirements above, mass-customization as a design and construction strategy which quite fit the situation of post-disaster housing development has the value to discuss in this paper.

Table 1. The short-tern impact of flooding for human and society. The Queensland research office put these defects into tangible and intangible ways.

Can the lost item be bought and sold for dollars?	Direct loss	Indirect loss
Yes-monetary (tangible)	building property; infrastructure collapse; individual materials; livestock	Damage of transport disconnection; Damage of business interruption; cost of infrastructure reconstruction
No-non-monetary (intangible)	normal trajectory of life is broken; disappearance of good memories; ecological damage	Post traumatic of human psychology; disruption to living ; loss of community; Short supply of environmental resources

In summary, the short-term chart impacts of flood issue can be summarized as economic and environmental factors. Disruption to transport and the damage of building construction could be seen as economic impacts. The pollution of water and ecological damage will be considered as an environmental factor. Though these issue analyses are still in the rough and early stages, it clearly delineates the flexibility, agility, and affordability needs of building materials and design strategies under the requirement of sustainability and environmental protection for post-disaster reconstruction. Hence, from mentioned needs and requirements above, organizing a road map of design framework for post-flood housing will take into consideration of these housing and occupants' status and needs. Based on the case study research of current post-flood issues, a series of post-flood defects and human needs or demands could be quantified as below figure 4 diagram. Those defects and disadvantages should be considered as problems during the reconstruction process with related solving strategies.

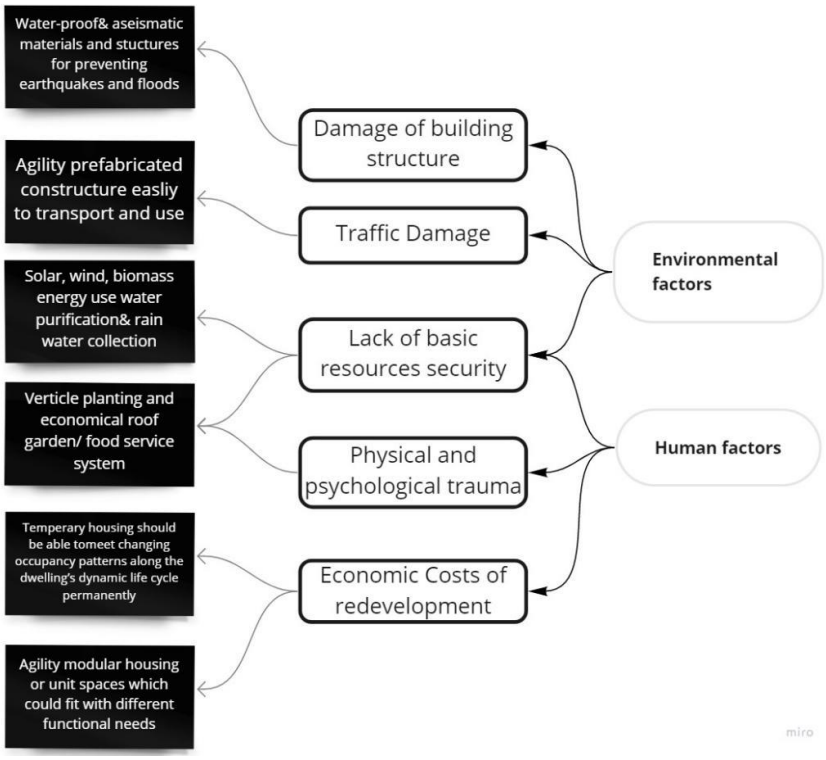


Figure 4. The summary of current environmental and human factors with potential related solving strategies based on the case study of current post-flood issues in Australia. This diagram was made by author.

2.2. Mass Customization for post-flood issues

"Mass customization is a manufacturing paradigm that enables customized and personalized design at a cost near mass production." said Dr Larsen(2009) has made a definition of the way to understand mass customisation. Mass customization has the ability of building unit affordably with a higher quality performance for its pre-fabricated in industry. Also, the short time period construction makes mass customization has a higher relevant to future architecture industry.[16] Joseph Pine published his book "Market of One- Creating Customer Unique Value through Mass Customization". With the aim of meeting the customer's needs, it explores a scientific strategy from production development to marketing to achieve low cost and high quality [17]. In building market, mass customization achieves a higher margin and is more advantageous for its mode of "one for all" to delivery products for a large amount of clients in agility, flexibility with lower unit cost [18].

With the mentioned advantages of mass customisation, it could be introduced as a concept to guide the post-flood reconstruction projects. From the perspective of construction, mass customisation can quickly form effective post-flood housing rather than simple shelters in a short period of time. Prefabricated modular units can be quickly replicated at a manageable cost. Then, the construction materials could be selected in local places without additional transaction process, since the 3d printing robots can be built at the base instead of people, thus avoiding traffic difficulties caused by floods in the process of transporting materials and manpower. Nevertheless, the research of human need related to mass customization in post-flooding house construction is still insufficient. The lack of previous projects could be proved to adequately address the aftermath of the disaster and the satisfaction of the affected population [17,18]. This paper will focus on the real human needs and demands to emphases on mass customisation for buildings with the aim of pushing a set of the feasible design scheme for the flood environment in Australia to make mass customisation more in line with diversified expectations and successfully implemented.

2.3. Human-centered personalisation for post-flood construction

2.3.1. IEQ and BS for post-flood housing design parameter collection

House, as a shelter which is protecting people's live and growth, plays an important role in connecting with human well-being [19]. In general, people may spend 66% of their living times at home during their whole life. This means that indoor environmental conditions will affect people's mood and happiness both physically and psychologically for a long time [20]. The same as post-flood victims, a living shelter with delicate design spaces which can fit victims needs and demands, in the long run, will make them feel more like home. However, in order to develop a post-flood housing design towards human well-being and comfortable use, intangible needs and comfort should be displayed through visible parameters and charts in a quantified way. Indoor environmental quality has a direct relationship with the level of occupants' conditions through a series of parametric quantification [21]. Nevertheless, indoor environmental quality as an evaluation component is hard to quantify psychological factors in a specific way due to the difficulty of intangible factors measuring. It usually could be quantified as physical factors of air, lighting quality, thermal and acoustic condition and so on [22]. Hence, in order to build a link of relationship between these tangible physical conditions with intangible psychological factors, IEQ should be combined with the theory of Behavior Settings (BS).

The theory of Behavior Settings (BS) is established by Barker. This theory mainly describes the relationship between individuals and the environment and explains the influences that 'units of the environment' (behaviour settings) have on human behaviors (Barker, 1968) [23]. This theory is helpful and useful in the architectural and urban planning field in that it can inspire people to consider how space and environments influence human and their behaviour. "It is to be incredibly powerful and incredibly useful in thinking about how does a physical a social setting actually influence what we do." (Dr Benjamin Cleveland) [24]. Post-flood housing reconstruction not just to build a shelter for self-living, but to re-build the social relationship for post-flood victims. Moreover, Barker defined behaviour Settings as independent spatial units with boundaries of time and space. They have a great

deal of coercive power over what happens within them [25]. Indeed, the environmental atmosphere has the power to impact human behaviors. The theory of Behavior Settings contains which can help to create more comfortable and targeted environments. Though it is not recognized by mainstream psychology yet, Behavior Settings has been widely approved by environmental psychology, ecological psychology and sociological social psychology) [26]. Interpreted from another point of view, people's behaviour can reflect their psychological feelings towards the environment settings. This approach quantifies the intangible psychology for post-flood victims by collecting data on their behaviors in space by observation and interview. Consequently, Behavior Settings provides a theoretical basis for exploring human psychological preference with the aim of collecting human-centered parameters in human psychology.

Furthermore, it intentionally perceives the psychological feeling of physical space reflected by human behaviours and then tests people's comfort level through behavioural data collection [27]. This paper will introduce IEQ parametric system to combine with BS to quantify the real needs for post-flood victims both in physical and psychological factors and the grading coefficient of building envelope. Testing the parameters by the EXD evaluation system provide feedback in a timely manner. Parameter data collection can clarify the demand factors and directions for the next design phase.

2.3.2. PTSD design strategies for victims' well-being

According to (Stanke C, Murray V,2012) study of post-flood impacted victims of common disorder from higher and, middle-income countries, it showed mental health problems such as depression and anxiety are more pronounced among adults affected by flooding than in the normal population. [28] Post-traumatic stress disorder (PTSD) occurs at all age, which has been widely focused on as an issue for post-disaster re-organization. "Well-being as a concept, it constitutes a broader category for people to understand happiness."(White, 2010) Well-being could be trace by research the relationship between human and environment, human and social interaction and human itself [28, 29]. In fact, interior and exterior spatial design have been linked to the interaction of environmental and mental health among PTSD post-flood victims. Same as other PTSD patients, they can benefit from the supportive spatial and environmental design to cope with the stress and negative emotions [30].

In detail, indoor space design can help patients enhance their response to therapy. Interior spacial scale, interior colour settings, daylight exposure, indoor window settings with the view of outside nature, and so on, as main elements control the consciousness of users by regulating negative emotions. The design of outdoor spaces can optimize patients' feeling of happiness, which is a way to get rid of PTSD. A green open space with wide vegetarian provided a high-quality space atmosphere for fresh air and reduced noise pollution. With the aim of psychological stress recovery and provoking physical activities for potential social interaction, outdoor spatial design has its value for post-flooded victims to overcome PTSD issues [28,29,30,31]. In order to achieve the transition from temporary shelter to permanent housing, providing a living community with PTSD therapy for post-flooded victims well-being, in the long run, is important as one of the design options in this paper.

3. Research Questions Formulation

Organizing a research question is of essential importance of exploring a valuable research framework of exploring a human-based mass customisation to improve the post-flood housing design and human well-being. Under the discussion of mentioned research above, there are some speciasl research aspects could be narrowed confirmed to support this research road map. The key question will revolve around the theme of exploring a theoretical framework of potential human-centered mass customisation and personalisation for improving the wellness of flood-affected families through the clear research scope and theoretical system of reference. Furthermore, to answer the key question, there are a series of questions that should also be considered in the following diagram. The key research question should be related to “how to build a road map for human-centered mass customisation and personalisation based on reviewing the post-flood housing and occupants’ status?”.

Under the proposed key research question, a series of sub-questions should be put forward to answer and research. These SQ1, SQ2, SQ3.....will clearly define each step of the framework organization and meet the need of each requirement in building this road map. Such as, "SQ1, What are the needs and demands of post-flood victims ?", "SQ2, What are the advantages of mass customisation that can support the post-flooding shelter evolution?", "SQ3, What are the detail theories should be considered as human-centered personalisation strategies into post-flood shelter revolution?" and so on...

4. Discussion

The literature review mainly exploring the theoretical relationship of mass customisation and human-based personalisation when applying to a post-flood housing re-development. Generally, post-disaster redevelopment inevitably needs to go through the following four stages, immediate relief within hours to a day, immediate shelter within days to a week, temporary housing within few weeks to months, long-term housing for years or more [32]. However, the effectiveness of temporary housing to long-term housing reconstruction is limited by a lack of planning and management by the government for its higher functional needs and recovery cost [33]. Based on the mentioned above, the research scope will focus on discussion about the transition from temporary housing to long-term reconstruction development from shelter to permanent housing with the aim of achieving post-flood families' wellness.

As the diagram of the theoretical framework shows in figure 5, this paper explores this temporary to permanent transition by researching the physical and psychological needs of post-flood victims and affected building envelope for human wellness implementation. Both human and building factors can directly or indirectly affect post-flooded families' behaviours, emotions, and safety to long-term living experiences [34]. Along with the factors research of post-flood shelter revolution, the key theories of human-centered mass customization and personalisation will be introduced during the design process. In addition, figure 6shows the relationship between the research procedure and the introduced theories. The diagram clearly shows how the theory framework has been considered and applied to the research process as it develops. In the process of quantifying the data of the post-flood impacts, indoor environmental quality (IEQ) for post-flood housing conditions and post-disaster traumatic therapy for human well-being will serve as a theoretical framework to guide and define as the process of human-centered personalisation design. Then, the output design prototype will be replicated under the basic human needs and demands.

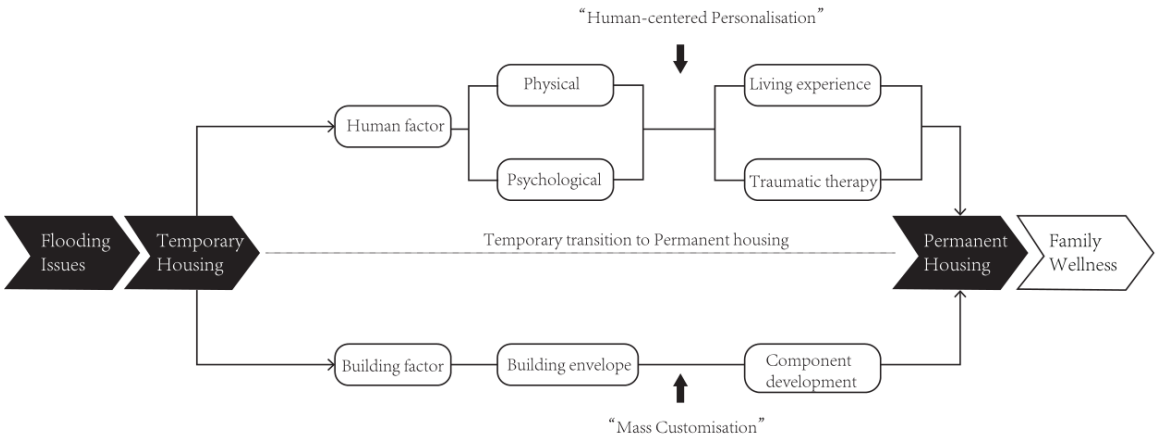


Figure 5. Diagram of theoretical framework for building and human factors. This figure is made by author.

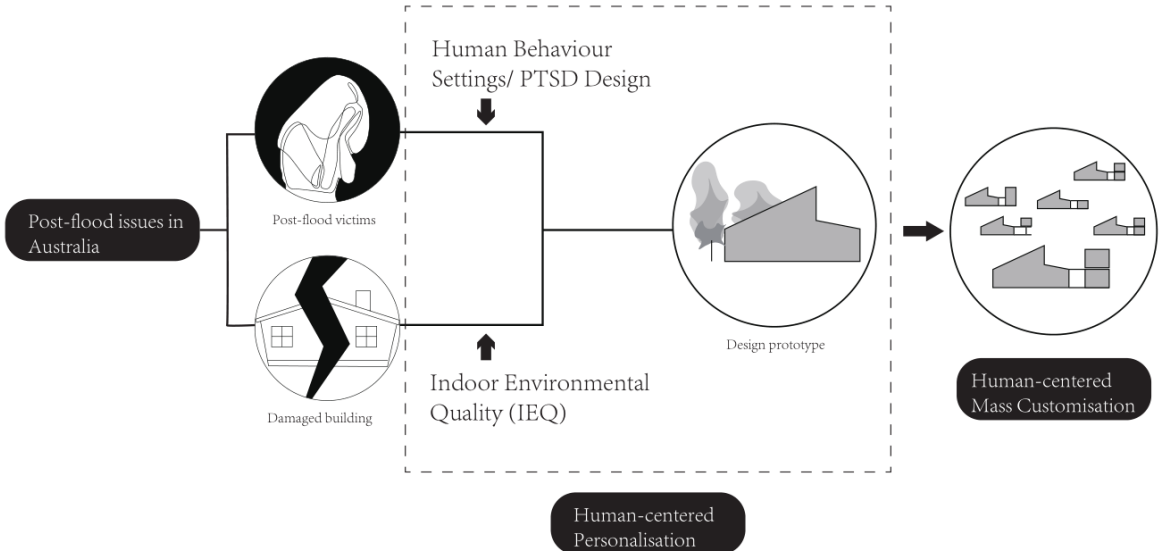


Figure 6. Diagram of the theories applied in the whole research framework organization. This figure is made by author.

It is the goal of humanitarian architecture to provide welfare and happiness for residents of vulnerable communities such as disaster areas and slums through construction. Humanitarian architects and designers have also sought to create and design safe, supportive and sustainable alternatives [28]. In order to achieve human-centered mass customisation and personalisation for post-disaster housing, human needs accompanied by their using experiences, should be considered seriously during the design process. At this moment, experience design has been successfully applied in industrial design, which is focusing on the improvement of products' interface to facilitate user satisfaction in meeting physical and psychological needs and demands. However, this concept of experience design is rarely applied in today's architectural design practices, and even it impact users' physical and perceived comfort levels in the built environment [35]. In order to achieve the personalized needs of post-area reconstruction, there must be a set of theories or a group of systematic evaluation criteria to measure and test the results of the design stage [36].

So far, the research and discussion on relevant fields are still in the primary stage. Meanwhile, there is no set of the perfect evaluation system to serve as the detection basis for the personalized satisfaction of post-disaster buildings, and many gaps are waiting to be filled. Nevertheless, EXD(Environmental Experience Design) as a cutting-edge research field has supported a deliberate attempt that affiliates experience design and environmental psychology with creating a suitable environment according to the needs and demands of users [31]. In detail, EXD is to propose design strategies and solutions to achieve the overall objectives of the building by analyzing the user's perception of the built environment. It could be seen as a functional analysis method to help identify "performance of user functionality" and improve the design process by asking what the user's needs are and how they are met to "meet the user's needs" [35,36,37].

In order to realize the transformation from mass-customization towards mass personalisation, for combining the convenience, affordability and assembly flexibility of mass prefabrication with the unique site environment requirements of post-flood reconstruction and the personalized needs of the affected population, EXD design strategy has its value as a tool to guide the design process and to test the outcome of this post-disaster housing development. The system through the phases of the set objectives for building and testing standards, giving clues as to the specific place of the action and clarifying the desired performance characteristics. It then identifying potentials and aimed outcomes by quantifying and defining design criteria step by step [38]. At present, the EXD designing tool is still at the forefront of theoretical research and evaluation based on existing buildings. Whether it can be used as a tool to guide and promote the design stage, and specifically applied to the design,

analysis and detection of post-disaster reconstruction projects, is still lacking sufficient research and attempts. This would be the next step for further exploration under this paper research.

5. Conclusions

Exploring the theoretical framework of human-centered mass customisation and personalisation for post-disaster shelter revolution enables human well-being. According to the selection and research of relevant theories, a reasonable research process framework is finally formed based on the needs of the post-disaster population and building. Through the relevant parametric data collection with design theories, a design prototype will be created to meet the needs and demands of post-flood victims. In addition, the testing process of data measurement which mentioned on the discussion, to ensure that the design results can be effectively feedback and improvement. Subsequently, the design methods and data collection methods corresponding to the design thinking framework will be another consideration in this study. This paper mainly focuses on the discussion and design of the research framework. It is expected that the specific design methods and data collection methods corresponding to such a design framework will be studied and determined in the next stage. At the same time, such a research strategy can help us rethink the principles and focus of post-disaster architecture design in other type of post-disaster building design during this Covid-19 situation.

Supplementary Materials: The following are available online at https://www.abc.net.au/news/:, Figure 1, (**a**) the disruptions of town housing after flood in Theodore of Queensland on January 1, 2011. ; (**b**) flooding water has submerged the Windsor Bridge in West Sydney, March 2011.

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