Non-structural Components influencing Hospital Disaster Preparedness in Malaysia

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Abstract. Hospital disaster preparedness refers to measures taken by the hospital’s stakeholders to prepare, reduce the effects of disaster and ensure effective coordination during incident response. Among the measures, non-structural components (i.e., medical laboratory equipment & supplies; architectural; critical lifeline; external; updated building document; and equipment & furnishing) are critical towards hospital disaster preparedness. Nevertheless, over the past few years these components are badly affected due to various types of disasters. Hence, the objective of this paper is to investigate the non-structural components influencing hospital’s disaster preparedness. Cross-sectional survey was conducted among thirty-one (31) Malaysian hospital’s employees. A total of 6 main constructs with 107 non-structural components were analysed and ranked by using SPSS and Relative Importance Index (RII). The results revealed that 6 main constructs (i.e. medical laboratory equipment & supplies; architectural; critical lifeline; external; updated building document; and equipment & furnishing) are rated as ‘very critical’ by the respondents. Among others, availability of medical laboratory equipment and supplies for diagnostic and equipment was ranked first. The results could serve as indicators for the public hospitals to improve its disaster preparedness in terms of planning, organising, knowledge training, equipment, exercising, evaluating and corrective actions through non-structural components.

1. Introduction
Preparedness initiatives for health sector have been promoted for the past 30 years across the globe. It was started during the World Health Assembly 1981 indicating that preventive measures and preparedness are fundamental importance. This is in-line with the International Decade for Natural Disaster Reduction (IDNDR) emphasizing the importance of preparedness particularly in the health sector [1]. The Hyogo Framework for Action (2005-2015): Building Resilience of Nations and
Communities to Disaster (under the Priority Four – reduce the underlying risk factors) mentioning that ‘hospitals safe from disaster’ is one of the initiatives to ensure all new hospitals are built with a standard level of resilience, remain functional, and implement mitigation measures to existing health facilities during disaster [2].

Since then, World Disaster Reduction Campaign on Hospitals Safe from Disasters (2008-2009) was launched with three purposes: protect the lives of patients and health workers by ensuring the structural resilience of health facilities; ensure health facilities able to function in the aftermath of emergencies and disasters; and improve the emergency management capacity of health workers and institutions [3]. Among the commitments for the Global Platform on Disaster Risk Reduction (in 2009) are: the national safety assessments for existing health facilities to be undertaken by 2011; whilst by 2015, actual action plans for safer hospitals to be developed and implemented in all disaster prone countries [4]. With regards to the commitment plan, a ten-point checklist for Making Cities Resilient has been launched in 2010 and one of the essentials checklist is the safety assessments for all health facilities [5].

Malaysia commits to maintain the safety of its cities, schools and hospitals under the 2011 Global Platform on Disaster Risk Reduction. As such Malaysia has pledged the safety of 3,231 hospitals, including clinics. The pledge was registered under the One Million Safe Schools and Hospitals initiatives, which encourages an individual, a family, a community, an organisation, a government, a business or any other entity to make a pledge for school or hospitals to make them disaster resilient [6]. Off late, disaster resilience hospitals outcome is being highlighted for Priority 1, 3 and 4 of Sendai Framework for Action (2015-2030).

Based on the commitment and initiatives in Malaysia, the hospital disaster resilience issue is inevitable to be embarked on. All respective stakeholders should cooperate in making the hospital strong, reliable and resilient for people in times of extreme events [7]. For example, hospital is a complex system that demands uninterrupted power and potable water, continual communications services, solid and liquid disposal and a steady supply of pharmaceutical products, medical and surgical supplies, specialised gases, chemicals and fuels [8]. Nonetheless, these necessities also represents a hazard if improperly stored, handled or maintained and could become a hazard during an earthquake, fire, explosion or other disaster [9].

Currently, it was observed that, in times of large scale natural disasters, hospitals were vulnerable in which the services temporarily or permanently interrupted due to the damage of their infrastructure [10]. Apart from natural disasters itself, the loss of non-structural components such as potable water, electric and telecommunication will reduce the hospital resilience [11]. In Malaysia, there have been several significant disasters related to non-structural components in public hospital. For instance, during the 2014 worst flood, an anaesthesiologist has had to intubate a baby in the dark after the generator ran out of fuel (in one of public hospitals in north-east Peninsular Malaysia). Another incident is the inability of the rescue helicopters to land due to unavailability of space. To make the matter worst the lifts are not functioning in the event of disaster [12].

Apart from flood, public hospitals have been negatively affected by fire. Again, in 2016, the intensive care unit in one of public hospitals in Johore, Malaysia was caught on fire and six fatalities were recorded. The results of the investigation revealed that the fire was caused by a burnt capacitor of the ceiling lights and there were flammable materials under the lighting that caused the fire to spread quickly [13]. Besides, some hospital facilities could not operate properly due to inappropriate equipment that contributes to disruption and cause the hospital vulnerable towards disasters [14]. This is in-line with Tokas [15] that emphasized, damage to non-structural components and systems can result in significant losses, temporary/partial/loss of operation/functionality (downtime), and patient or staff injuries and in some cases loss of life. It has been postulated by Hossain & Elahi [16] that in future disasters particularly earthquakes, at least 50% of losses due to non-structural components. According to World Health Organization (WHO) [17], hospitals have a complex network of electrical, mechanical and sanitary facilities as well as a significant amount of costly equipment all of which are essential both for the routine operation of the hospital and for emergency care during disasters. It can be deduced that, the entire above are related to non-structural components that are essential in ensuring hospital’s disaster
preparedness. Hence, the objective of the paper is to identify and rank the non-structural components that contribute to disaster preparedness of hospitals in Malaysia.

2. Non-Structural Components influencing Hospital Disaster Preparedness

The non-structural components of a building include all parts of the building and its contents apart from the structure (columns, floors and beams). Common non-structural components include ceilings; windows; office equipment; computers; inventory; file cabinets; water tanks; generators; transformers; heating, ventilating, and air conditioning (HVAC) equipment; electrical equipment; furnishings; and lights [18]. These non-structural components of a building are classified into: architectural components (i.e. ceilings, windows and doors), medical and laboratory equipment, lifelines (i.e. mechanical, electrical and plumbing installations) and safety and security issues [19].

Table 1 shows eight (8) sources of existing hospital preparedness assessment instruments involving non-structural components that have been implemented by international agencies and past researchers. The preparedness assessment instruments are in the various forms (i.e. questionnaire and checklist) focusing on all type of hazards (i.e. natural and man-made). However, for the purpose of the study, the non-structural components are merely extracted from the assessment instruments.

| Components | Sources | No. of items |
|------------|---------|--------------|
|            | [8]     | [20]         | [9] | [21] | [19] | [22] | [23] | [24] |             |             |             |
| 1. Updated building documents/ drawings | √ | √ |             | 3   |             |             |             |             |             |             |             |
| 2. Architectural items | √ | √ | √ | √ | √ | √ | 11 |                               |             |             |
| 3. External items | √ | √ | √ | √ | √ | √ | 4  |                               |             |             |
| 4. Critical lifeline system |                               | 72 |                               |             |             |
|       • Electrical systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Telecommunication systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Water supply systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Medical gas systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Fuel storage systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • HVAC systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Fire protection system | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Waste management systems | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
|       • Manuals of Instructions for the Operation, Preventive Maintenance & Restoration | √ | √ | √ | √ | √ | √ | √ |                               |             |             |
| 5. Medical Laboratory equipment and supplies for diagnostic and treatment | √ | √ | √ | √ | √ | √ | 11 |                               |             |             |
| 6. Equipment and furnishing | √ | √ | √ | √ | √ | √ | 6  |                               |             |             |
| Total |             |             |             | 107 |             |             |             |             |             |             |             |
In that assessment, six (6) main components comprises 107 items (i.e., updated building documents/drawings/plans- 3 items; architectural- 11 items; external- 4 items; critical lifeline systems- 72 items – electrical, telecommunication, water supply, medical gas, fuel storage, HVAC systems, fire protection, waste management, and manuals of instructions for operation, preventive maintenance and restoration; medical laboratory equipment and supplies used for diagnostic and treatment- 11 items; and equipment and furnishing- 6 items) are considered as utmost critical. These significant components will be discussed in turn.

The first component for hospitals and health facilities ought to have is updated building documents/drawings/plans (i.e., approved construction plans; as-built plans; updated as-built plans; and occupancy permit) available at all the time [19]. The purpose of the as-built drawings is to indicate those professional involved who will be liable and responsible for the integrity of the building with regards to architectural and engineering aspects. In addition, the as-built plans would provide the building’s interior knowledge which is necessary for future maintenance, upgrading and renovation. The updated as-built plans recorded several renovations, alteration and that succeeding designs for change/ renovation act as reference documents. To be more precise, the occupancy permit indicates the hospital is in a suitable condition for occupancy [21]. In addition, illustrating building for safety in the means of three dimensions drawing provide easier way to communicate the technical information to local builders and the building owners [25].

On the contrary, architectural components comprises of the safety of the roofing and ceilings; doors and windows; walls, divisions, partitions and floor coverings [24]. Apart from that, the components includes stairways and ramps; elevator; corridors; railing and parapets; and other architectural elements (cornices, ornaments and signs) [22]. The third component is external and encompasses of movement outside hospital buildings (i.e., parking lots; pedestrian and walkways), access routes, exit and evacuation routes, and perimeter walls or fencing. The external components are subjected to none or minor obstacles and damages that would cause the hospital to be impassable [22]. Lesson learnt from previous 2011 earthquake in Christchurch, New Zealand, the impassable roads and communication difficulties resulted in little pre-hospital triage or treatment for most of those who presented early [26].

The fourth component is critical lifeline system. Hospital water and electricity supply which are classified as critical engineering infrastructure components are the most threatened during disaster and faces high risk of failure [27]. On the other hand, communication is vital to the successful management of medical and other critical services during disasters [28]. It also consist of medical gas system, fuel storage, heating, ventilation, and air-conditioning (HVAC) systems, fire protection, waste management and manuals of preventive maintenance for critical lifeline systems [22].

The fifth component is medical laboratory equipment. In most hospitals, a large range of medical and diagnostic equipments are utilized to provide treatment to patients. The hospitals’ stakeholders should maintain the condition, safety and stability of all equipment and protect it from damage that could cause injury to occupants and disrupt the functioning of the hospital services [19]. Blackout 2003 in North East-Central area of United States within the distribution of Niagara electric power grid has resulted to various hospital electrical issues particularly with the medical laboratory equipment. The equipment (i.e. laboratory; radiology; CT scanner) interconnects are off-line and unable to run certain laboratory tests [29].

The sixth component however is equipment and furnishing that are equally important to be addressed. These equipment and furnishing could be badly shaken, overturn or slide crashing down and cause injuries to people during disaster [30]. Hence, the six components listed above are the key non-structural components influencing hospital’s disaster preparedness. Given the above, the items act as input factors for further data collection through a questionnaire survey.

3. Research Methodology
The research utilised a questionnaire survey method based on six (6) non-structural components (i.e. updated documents/drawings/plans; architectural; external; critical lifeline; medical laboratory equipment; and equipment and furnishing). In order to measure these factors, a five-point Likert scale
items were deployed for which the respondents were asked to indicate the level of importance on these components representing their main constructs. Judgmental purposive sampling is used based on the expertise of respondents on the subject matters. A total of 51 numbers of questionnaires were sent out to Malaysian hospital’s staff over a period of one month (24th April to 26th May, 2017). Out of this, 31 questionnaires were completed and returned representing a response rate of 60.78 percent. The average response rate are due to the data collection are still on-going on further response for the purpose of PhD main data collection.

Given, the education level (min- diploma, max- PhD) and years of experience (min- 4 months, max-30 years), it could be inferred that the respondents are prominent. In addition, 26 (83.9%) of the respondents have encountered disasters during their working life. A total of 16 types of disasters were reported by 26 respondents, with some having experienced more than one disaster during past working years. The majority were flood (n=12), followed by computer failure (n=11) and power outages (n=11). Thus, it is reasonable to infer that the respondents have sound knowledge on the research. The outcomes of the questionnaires were analysed by using SPSS Version 24 for descriptive statistics and Relative Importance Index (RII) for ranking.

4. Reliability of Data
In the current study, the Cronbach alpha coefficient was .70 [31]. The results revealed that the Cronbach’s alpha value for non-structural components (updated documents/drawings/plans- .860; architectural-.980; external-.934; critical lifeline-.957; medical laboratory equipment-.943; and equipment and furnishing-.938) which are higher than .70. The outcomes indicated that the data collected are interrelated and reliable.

5. Findings: Importance of Non-Structural Components influencing Disaster Preparedness
Table 2 presents non-structural components influencing hospital’s disaster preparedness. The analysis primarily deals with ranking the variables based on their mean score values (SPSS) and Relative Importance Index (RII) to determine their level of importance. RII was used to rank the non-structural components through the formula: \( RII = \frac{\sum W}{A \times N} \), where ‘W’ is the weight given to each factor by the respondents within the range of 1 to 5 using the same Likert scale, ‘A’ is the highest weight and ‘N’ is the total number of respondents. The results revealed that six (6) main components of the non-structural components are rated as ‘very critical’ by the respondents by which medical laboratory equipment and supplies for diagnostic and treatment (mean score= 4.659; SD=0.828; & RII= 0.890) was ranked first. It has been noted that sufficient pharmaceuticals and medical supplies and equipment are essential to provide care for the patients. It has been identified as one of key resource categories to successful hospital surge capacity implementation [32].

| Non-Structural Components                                      | Mean | SD    | RII  | Rank | Criticality |
|---------------------------------------------------------------|------|-------|------|------|-------------|
| 1. Medical Laboratory equipment and supplies for diagnostic and treatment | 4.659 | 0.828 | 0.890 | 1    | V. Critical |
| 2. Architectural                                              | 4.597 | 0.546 | 0.889 | 2    | V. Critical |
| 3. Critical lifeline system                                   | 4.518 | 0.637 | 0.887 | 3    | V. Critical |
| 4. External                                                   | 4.502 | 0.692 | 0.873 | 4    | V. Critical |
| 5. Updated building documents/ drawings / plans               | 4.472 | 0.758 | 0.841 | 5    | V. Critical |
| 6. Equipment and furnishing                                   | 4.468 | 0.720 | 0.815 | 6    | V. Critical |

5=Extremely Critical; 4= Very Critical; 3= Critical; 2=Somewhat Critical; 1= Not Critical
In order to identify the prominent non-structural components influencing hospital’s disaster preparedness a detail descriptive analysis (SPSS) and ranking-based (RII) are conducted between the three (3) utmost critical non-structural components (i.e. medical laboratory equipment, supplies for diagnostic and treatment; architectural; and critical lifeline system).

Table 3 presents the mean, standard deviation and RII scores for medical laboratory equipment and supplies for diagnostic and treatment components. The results revealed that eleven (11) components associated with medical laboratory equipment and supplies for diagnostic and treatment are rated as ‘very critical’ by the respondents by which condition and safety of radiology and imaging equipment (mean score= 4.548; SD=0.624; & RII= 0.910 ) was ranked first. It has been suggested that radiology and imaging equipment (i.e. computed tomography (CT); positron emission tomography (PET); and MRI) should be a part of any preparation strategy against water damage, structural damage and power outage by which caused by natural disasters. Healthcare providers are needed to triage the facilities itself by restoring the services that are most critically needed in the wake of disasters [33].

Table 3. Medical Laboratory equipment and supplies for diagnostic and treatment components influencing Hospital Disaster Preparedness.

| Medical Laboratory equipment and supplies for diagnostic and treatment components for | Mean | SD  | RII | Rank | Criticality |
|-------------------------------------------------------------------------------------|------|-----|-----|------|-------------|
| 1. Radiology and imaging                                                             | 4.548| 0.624| 0.910| 1    | V. Critical |
| 2. Emergency care services unit                                                      | 4.548| 0.723| 0.910| 2    | V. Critical |
| 3. Intensive or intermediate care unit                                               | 4.548| 0.723| 0.910| 2    | V. Critical |
| 4. Operating theatres and recovery                                                  | 4.516| 0.626| 0.903| 3    | V. Critical |
| 5. Emergency care for burns                                                          | 4.516| 0.626| 0.903| 3    | V. Critical |
| 6. Nuclear medicine and radiation therapy                                           | 4.484| 0.677| 0.897| 4    | V. Critical |
| 7. Obstetric emergencies neonatal care                                              | 4.484| 0.724| 0.897| 5    | V. Critical |
| 8. Laboratory equipment and supplies                                                 | 4.387| 0.803| 0.877| 6    | V. Critical |
| 9. Equipment and furnishings in the pharmacy                                        | 4.355| 0.877| 0.871| 7    | V. Critical |
| 10. Equipment and supplies in the sterilization services                              | 4.290| 0.973| 0.858| 8    | V. Critical |
| 11. Other services                                                                   | 4.258| 0.815| 0.852| 9    | V. Critical |

5=Extremely Critical; 4= Very Critical; 3= Critical; 2=Somewhat Critical; 1= Not Critical

On the other hand, Table 4 presents the mean, standard deviation and RII scores for architectural components. The results revealed that eleven (11) components associated with architectural are rated as ‘very critical’ by the respondents by which internal walls and partitions (mean score= 4.516; SD=0.677; & RII= 0.903) was ranked first. It has been postulated that for a performance-based design approach, it is important to distinguish when the wall partition assemblies collapse and when their effectiveness as a smoke and flame barrier is compromised [34].
Table 4. Architectural components influencing Hospital Disaster Preparedness.

| Architectural components                                             | Mean  | SD    | RII   | Rank | Criticality  |
|---------------------------------------------------------------------|-------|-------|-------|------|--------------|
| 1. Internal walls and partitions                                     | 4.516 | 0.677 | 0.903 | 1    | V. Critical  |
| 2. Major damage and repair of non-structural elements                | 4.516 | 0.811 | 0.903 | 2    | V. Critical  |
| 3. False or suspended ceilings                                       | 4.484 | 0.724 | 0.897 | 3    | V. Critical  |
| 4. Roofing                                                          | 4.484 | 0.724 | 0.897 | 3    | V. Critical  |
| 5. Doors, exits and entrances                                        | 4.484 | 0.851 | 0.897 | 4    | V. Critical  |
| 6. Elevator system                                                  | 4.452 | 0.810 | 0.890 | 5    | V. Critical  |
| 7. Stairways and ramps                                              | 4.452 | 0.925 | 0.890 | 6    | V. Critical  |
| 8. Windows and shutters                                             | 4.419 | 0.992 | 0.884 | 7    | V. Critical  |
| 9. Movement inside the building (e.g. corridors)                    | 4.387 | 0.989 | 0.877 | 8    | V. Critical  |
| 10. Other architectural elements (e.g. cornices, ornaments, chimneys, signs) | 4.355 | 0.839 | 0.871 | 9    | V. Critical  |
| 11. Railing and parapets                                             | 4.355 | 0.950 | 0.871 | 10   | V. Critical  |

5=Extremely Critical; 4= Very Critical; 3= Critical; 2=Somewhat Critical; 1= Not Critical

Table 5 presents the mean, standard deviation and RII scores for critical lifeline components. The results revealed that nine (9) components associated with critical lifeline are rated as ‘very critical’ by the respondents by which medical gas systems (mean score= 4.665; SD=0.559; & RII= 0.933) was ranked first. It has been highlighted that in order to enhance the performance of alternative positive-pressure ventilation equipment (PPV) during disaster, medical gas conservation ought to be used efficiently (operate for periods of time without reliable electricity) and should not require pressurized medical cases as the sole power source [35].

Table 5. Critical lifeline components influencing Hospital Disaster Preparedness.

| Critical lifeline components                                      | Mean  | SD    | RII   | Rank | Criticality  |
|------------------------------------------------------------------|-------|-------|-------|------|--------------|
| 1. Medical gas systems                                           | 4.665 | 0.559 | 0.933 | 1    | V. Critical  |
| 2. Fire protection systems                                       | 4.611 | 0.727 | 0.922 | 2    | V. Critical  |
| 3. Electrical systems                                            | 4.529 | 0.685 | 0.906 | 3    | V. Critical  |
| 4. Fuel storage                                                  | 4.476 | 0.726 | 0.895 | 4    | V. Critical  |
| 5. Waste management systems                                      | 4.476 | 0.815 | 0.895 | 5    | V. Critical  |
| 6. Water supply systems                                          | 4.438 | 0.796 | 0.888 | 6    | V. Critical  |
| 7. Manuals of Instructions for the Operation, Preventive Maintenance & Restoration | 4.265 | 0.775 | 0.853 | 7    | V. Critical  |
| 8. Heating, ventilation, air-conditioning (HVAC) systems         | 4.244 | 0.796 | 0.849 | 8    | V. Critical  |
| 9. Telecommunication systems                                     | 4.203 | 0.853 | 0.841 | 9    | V. Critical  |

5=Extremely Critical; 4= Very Critical; 3= Critical; 2=Somewhat Critical; 1= Not Critical

Given the above, it could be inferred that taking proper corrective actions on these six (6) non-structural components (i.e. updated documents/drawings/plans; architectural; external; critical lifeline; medical laboratory equipment; and equipment and furnishing) could enhance the hospital’s disaster preparedness resulting to effective coordination during incident response.
6. Conclusion
This paper has presented the findings on non-structural components influencing hospital’s disaster preparedness in Malaysia, as the major novelty of the research. Compare to the past researchers, the research employed a thorough extraction of non-structural components from various assessment instruments established by international agencies such as: World Health Organization Europe Region Office (EURO); World Health Organisation Western Pacific Region (WPRO); Pan American Health Organization (PAHO) and World Health Organization (WHO). A total of 6 main constructs with 107 non-structural components were identified and analysed in the forms of SPSS (descriptive statistics) and Relative Importance Index (RII).

The results revealed that six (6) main components (i.e. updated documents/ drawings/ plans; architectural; external; critical lifeline; medical laboratory equipment; and equipment and furnishing) are rated as ‘very critical’ by the respondents by which medical laboratory equipment and supplies for diagnostic and treatment was ranked first. Laboratory equipment and supplies are required to be sufficient and able to perform its function during disaster. Maintaining the condition and safety of the equipment will provide uninterrupted diagnostic and treatment services to the patients. Nevertheless, the other remaining components should not be deserted in order for greater disaster preparedness. By identifying those components, various stakeholders could prepare for all the risks related to disasters (i.e. natural; biological; societal; technological-buildings related; and mass casualty incidents). The components are needed to examine and assess the risk, whether in the form of inventory or questionnaire to identify the likelihood of catastrophic failure (non-structural) in the event of disasters. It is inevitable that there is a need to provide guidelines for non-structural components to the hospitals’ stakeholders due to the fact that those components are the key to continuous operation of a hospital building.

In addition, it is notably that the success of creating disaster preparedness in the hospital would depend on different organisational culture (i.e. process vs. results oriented; employee-oriented vs job-oriented; parochial vs professional; open systems vs closed system; loose control vs tight control; and normative vs pragmatic) among hospital’s stakeholders. The benefits improving these factors would allow hospital’s stakeholders to cooperate among themselves in achieving the same goal by which improving disaster preparedness for the hospital building. Despite the importance of organisational culture influencing hospital disaster preparedness, for the purpose of this paper, the study is not thoroughly explored.

Given the above, in order to complement the development of the non-structural components, the elements of planning, training, monitoring and continuous corrective actions of the non-structural components should be associated. It is believed that the functionality and operability of the non-structural components could not be delivered until effective strategies are implemented hence resulting in minimizing the non-structural damages. These strategies will be incorporated in the functional components (i.e. SOP; guidelines; operational plans; human resources and training; and monitoring and evaluation) which will be discussed in the next paper.

To recapitulate, non-structural components are essential to be implemented in order for better preparedness. Although the sample is small (31 respondents) for the time being, the findings could not be discredited. The research presented in this paper is part of an on-going PhD research study at the Faculty of Architecture, Planning & Surveying, UiTM Malaysia to develop an evaluation framework of disaster resilience through disaster preparedness for public hospitals. The results could serve as indicators for the public hospital’s stakeholders in Malaysia to improve its preparedness and enhancing its resilience.

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