

## Review Report on

“Natural hazard risk of complex systems – the whole is more than the sum of its parts: I. A holistic modelling approach based on Graph Theory” and

“Natural hazard risk of complex systems – the whole is more than the sum of its parts: II. A pilot study in Mexico City”

### *General summary*

I carefully read the second version of both the manuscripts which is organized in two parts: part I describes the proposed “graph theory” approach, and part II illustrates an application of the graph theory to a pilot study in Mexico City. The author(s) argues that from a more practical perspective, these two companion papers may address different audiences: part I is targeted to a more general audience who may be interested in understanding the foundations of the approach, while part II points to technical experts and researchers who may want to implement this approach for their own practical applications.

I identified various loopholes in the written manuscripts which needs to be sincerely addressed before this manuscript could proceed with publications, which are as follows:

#### 1. *Unjustified strong claim*

I do not agree with the author(s) claim that this manuscript has proposed a new approach. Graph theory is an existing approach which has invaded almost all branches of science (as clearly mentioned by both the reviewers in their first round of review). This manuscript only extends its application to “Natural hazard risk of a complex system”. I would suggest moderating the tone of the paper mentioning that they have used/applied graph theory for X purpose properly giving credit to all seminal papers.

*For instance, see Part I: page 6, second aim, “to propose a new approach.....”.*

#### 2. *Confusing between Graph and Network theory, terms and concepts*

Reading both the manuscripts it seems that the author(s) did not do a detailed (breadth and depth) literature review. For instance, (a) throughout both the manuscripts authors used particular terms associated with network and graph interchangeably which is not scientifically correct and created confusion; (b) many seminal papers, on which graph theory is based, are omitted from the citation list, (c) vertices and edges are particularly associated with graph whereas node and links with network. Either stick to one terminology or highlight the difference between graph and network and make a statement that all terminologies (Vertices and node, edge and link) are same and they are using it without any distinction.

Further, in a single statement, the study is using Network and graph simultaneously, in my opinion, which is not acceptable. For instance, “*Part I: Section 2.1, In the scientific community, the mathematical properties of a network are studied using Graph theory,*”

Also, I am not fine with the definition of Graph theory. In part I, the author write that Graph Theory is the branch of mathematics that studies the properties of **networks** (P6/L143) whereas in the

part II author states that Graph Theory is the branch of mathematics that studies the properties of graphs (P2/L37). Does the author think that Graph and Network are exactly the same? Well, in my understanding they are different indeed there is overlapping.

I am struggling to understand why authors decided to call the approach based on Graph theory and not Network theory. What makes it really a graph theory? Does the author agree that “a network is a diagrammatical representation of some physical system or structure whereas a graph, on the other hand, is a mathematical notion that represents only the structure of a network without physical meanings?” If yes, I would prefer to call approach based on Network theory. Further, I also have a notion that Graph theory largely has its root in Mathematics where it has been used to conceptualize the problems into a graph whereas Network theory provides a set of techniques for analyzing such graphs. Further, many concepts such as multi-layer network, dynamic network, coarse-graining our flourishing with network theory only.

At last, I would say that I am not strict with terminology since every researcher has its own notion but indeed I am more inclined to use Network theory instead of graph theory. Further, if the author continues to go with graph theory makes sure manuscripts clearly deal with the terms and concepts of only graph theory.

### 3. *Structuring and content of part I*

The author(s) argues that part I is targeted to a more general audience who may be interested in understanding the graph theory.

Being a general audience, I sincerely have difficulties to understand many terms theoretically as well as mathematically, presented examples, terminologies, mathematical concepts and more importantly the aim. As both the reviewer mentioned (reviewer 2, specifically) I feel the paper is disorganized and at last, it does not convince me. My very specific observations are as follows:

*Abstract: L14, this paper proposes a new holistic approach to assess the risk in a complex system based on Graph theory.* What is the approach? To identify vertices of a graph, setup edges and analyze the resultant graph? I feel it is a standard way, isn't it? Then, how this manuscript justify the approach? Only based on a hypothetical city example, which is very subjective. I am still struggling to understand what this manuscript contributes to the existing knowledge.

My biggest concern is that the study deals with graph theory but does not provide any mathematical details. Which is unacceptable in such kind of study.

Page 6/Line 158, section 2.1: electrical power grid, the internet, highway and neural network, being general audience I am not able to visualize what is vertices and edges in above-mentioned graphs and importantly directions (if directed network).

Coming back to the aim of the paper, the entire study deals with the directed network and hence since the beginning the author (s) need to put more stress on the directed network. For example, section 2.1 need more words, more examples and mathematical notions about a directed network.

*The author(s) take many different examples to explain the network concept whenever they need, without any coherence structure, For instance, P13/L351: As an example, in a road graph, a bridge node has a higher value of betweenness because all the nodes of a sub-graph (e.g. one side of the river) need to*

pass through the bridge node in order to connect to the nodes of the other sub-graph (the other side of the river). In the case of bridge failure, the two sides of the river are isolated and the original road graph splits into two sub-graphs.

What is the road graph? What are the edges and vertices? What is the bridge node? How to decide? Do we have a river in the road graph? It is all theoretical and very subjective. Not acceptable and convincing.

Another example is section 3.1.3 of the earthquake.

#### 4. Mathematical details and graph theory measures

Page 7/line 194: A node with high hub value points to many other nodes, while a node with high authority value is linked by many different hubs. Mathematically, the authority value of a node is proportional to the sum of the node hubs pointing to it and the hub value of a node is proportional to the sum of the authority of nodes pointing to it.

Is this definition provided by the authors exclusively? If not, I couldn't find any citation to valid above-written definition.

I am wondering whether or not this problem has a unique solution. Author claim that this article is suitable to a general audience, being an expert in network theory I am unable to understand it. I request to take a dummy graph (very simple) and explain how the author(s) setup direct graph, decide hubs, authority values and hub value of a node.

Page 8/line 201: Depending on the statistical properties of the degree distribution, there are two broad classes of networks: homogeneous and heterogeneous..... Again, is this definition provided by the authors exclusively? If not, I couldn't find any citations. Is the author sure about the above-mentioned statement? I am struggling to validate this definition. What do authors mean by the homogeneous network? What are the properties of the homogeneous network? I assume the author might be pointing to a regular network because, by definition, each node in a regular network has the same number of links. If so, this is a very absurd statement.

So as per the claim, all the network having Poisson distributions are homogeneous? This again makes my conviction strong that authors did not check the literature appropriately.

What a random network is, as mentioned in (P8/L224)? Further,  $P_c = 1/\bar{K}$ , I do not understand this mathematical expression?

Section 3.1.2: P12/L343: closeness: a shorter path between a node and the network? Do you mean shorted path between a node and all other nodes? Difficult to understand, please Rewrite it.

Table 1: closeness:

Which is closeness author talking about? I did not understand the definition? Is it closeness centrality? If yes, please rewrite it to "shortest path length from the node to every other node in the network". Again mathematical formulas of all the terms are unavoidable.

Hub? Does the author mean two different hubs in the network? Hub value of a node and hub node itself? Confusing. Make it clear.

I just did not understand the concept of percolation and others in the absence of proper mathematical definitions. Mathematical details are indeed important.

5. *Section 2.2*

*"We proposed an approach based on the following two major phases". I appreciate the author's creativity in designing the text and section however, this is more general and clubbed into one section called graph construction to reduce the redundancy.*

*In an entire section of based on topology, I couldn't see any seminal paper cited. Not appreciated. Did the author has heard about coarse-graining of network or topological scale in the network? It goes in the same direction what the author has explained (entire network, community and a single node).*

*P10/L279: it is necessary to define rules? I would be happy to see the rules since the author claim that they are proposing an approach and hence very consolidate approach with the full explanation is needed. Section 2.2 from part II should have been here.*

6. *Section 3.2*

*I am sorry to the author but I couldn't find anything new here.*

7. *Discussion*

Too much repetition, again and again, that we have proposed an approach which can solve all the problems

Page 16/line 443: *"This new approach...."* Is it really a new approach?

Line 443 to line 454 should go to introduction.

Line 455 and line 342: *"The proposed approach is suitable for multi-hazard assessment" many times repeated.*

8. *Other minor comments*

Fig. 1c could be improved by weighting the links.

Fig.3: there are 9 blocks, not 8. Correct in the text (Section 3.2, line 403).

*Summary*

I am not convinced with the author's claim that this study is suitable for General Audience. The author (s) has tried to oversell the content without giving proper justification and showing any results. Indeed it fails in giving credit to previous studies. Many seminal papers are missing and it clearly seems that vast and in-depth literature review is missing. I found many terse and absurd statements. The study clearly lacks in terms of mathematical justifications. Too many over claim statement such as approach "Could be used for risk mitigation strategies", "Similar analysis could be carried out for betweenness to obtain more insights into the risk assessment". Therefore, I recommend rejection of part I.

Nevertheless, it was a great attempt and I motivate the team to work and explore more to fill the gaps. Due to this, I am afraid that the entire manuscript should be rejected, and the authors should be given an opportunity to merge both the manuscripts and resubmit. I am willing to review the contribution, if the authors want to submit a revised work. I hope I am not unduly discouraging, but the problems detailed above are sufficiently severe for the work not to be considered for publication in the current form. However, I do think that the authors have applied an interesting methodology that should be investigated thoroughly, and which may lead to important breakthroughs in the area of interest. Therefore, I encourage the authors to further pursue this method, and I hope my suggestions are useful for this endeavor.

### ***Few specific comments to part II***

“Natural hazard risk of complex systems – the whole is more than the sum of its parts: II. A pilot study in Mexico City”

I have read both the articles in detail and based on my observation I think it is well clear that part II needs major revisions, rewriting and restructuring. I suggest the author to moderate tone in the revised version, specifically focus on the primary goal and go through the seminar paper published in other domains. Please remove all the content which is not relevant to the objective. For example, discussion on the homogeneous and heterogeneous network, unsuitable examples etc. Kindly do not provide off-topic details.

If the author will do that I am sure merging both the papers will not be lengthy at all. The introduction of part II is not convincing and always directs the readers to part I.

### ***Minor comments***

*Page 6/line 151: closeness centrality measures.....which it is.....remove it.*

### ***Summary***

As indicated merging both the manuscripts will be an ideal option. Therefore, I am not providing content-specific comments at this stage since the author(s) needs to majorly restructure the content.