A systems thinking approach to value-added services adoption in national research and education networks

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***Abstract*—The growing importance of advanced or value-added services (services over and above basic connectivity services) in national research and education networks (NRENs) is well understood in the research and education community. These services are made available to further distinguish and enhance national research and education networks' offerings from that of commercial internet service providers. Systems thinking allows a 'bigger view' of a situation to be analyzed. This paper presents a model that was developed, refined and validated using design science research methods and a systems thinking approach. The model is a causal diagram developed to enable the visualization of how factors in the NREN services adoption context are interrelated. The model was refined and validated with international NREN experts. As a result of the evaluation stage, a shared mental model and understanding of the NREN's advanced services delivery ecosystem was developed. The model can be used as a communication and decision-making tool to facilitate services adoption from NRENs to their research and education communities.**

Keywords—NREN, Design science research, Causal diagram, Advanced services, Value-added services, ICT service adoption, Services management

I. Introduction

The primary mission of a national research and education network (NREN) is to act on behalf of their country's higher education community in providing advanced information and communication technology (ICT) services, to connect academic institutions to one another's networks and resources, both nationally and globally. Advanced or value-added services (services over and above basic connectivity services) in NRENs are provided to further distinguish and enhance the NRENs offering in contrast to those from that of internet service providers (ISPs). NRENs continue to focus more and more on services "beyond connectivity", as this is where they should be able to add specialized services and great value to the research and education (R&E) community, far more effectively and efficiently than a commercial ISP would be able to do [1]–[7].

The NREN's shift in focus from providing connectivity only, to providing other additional services, has been reinforced in conference themes e.g. the theme at the 2015 UbuntuNet Conference was "Beyond Connectivity: The road to NREN maturity" [8] . Special interest groups (SIGs) such as GÈANT's[1] SIG on the management of service portfolios have also been developed to focus on topics around NREN service management [9].

Services offered by NRENs to their beneficiaries, who are usually the countries' higher education and research institutions, are chosen to further R&E goals that range from videoconferencing, data transfer movement, trust and authentication, to cloud and cybersecurity services.

Service management and delivery is a team effort between the NREN and its beneficiary institutions involving many factors that affect the likelihood of the adoption of an advanced service being offered by the NREN to its beneficiary institutions.

II. Research Problem

Although the importance of adding value-added services to the NREN's portfolio is well documented and accepted [1]–[7] , there is still much to understand, learn and explore in what can be seen as a developing discipline. Bech's [1] presentation titled "Services management in an NREN environment", posits that NREN services management should be a discipline in itself. He argues that all NRENs are already doing services management to some extent but suggests a need for the documentation of best practices and experiences so that NRENs can be more efficient and learn from one another.

NRENs have specific requirements, characteristics and are not designed to generate large scale profits. Therefore, the management of NREN services should be different from typical ISPs.

A study was conducted fifteen years ago, where Galagan [11] models various NREN management topics. However, his study does not look at the management of NREN value-added service processes, which becomes more relevant as NRENs grow and mature [4].

[1] GÉANT is the pan-European data network for the research and education community. It interconnects national research and education networks across Europe.

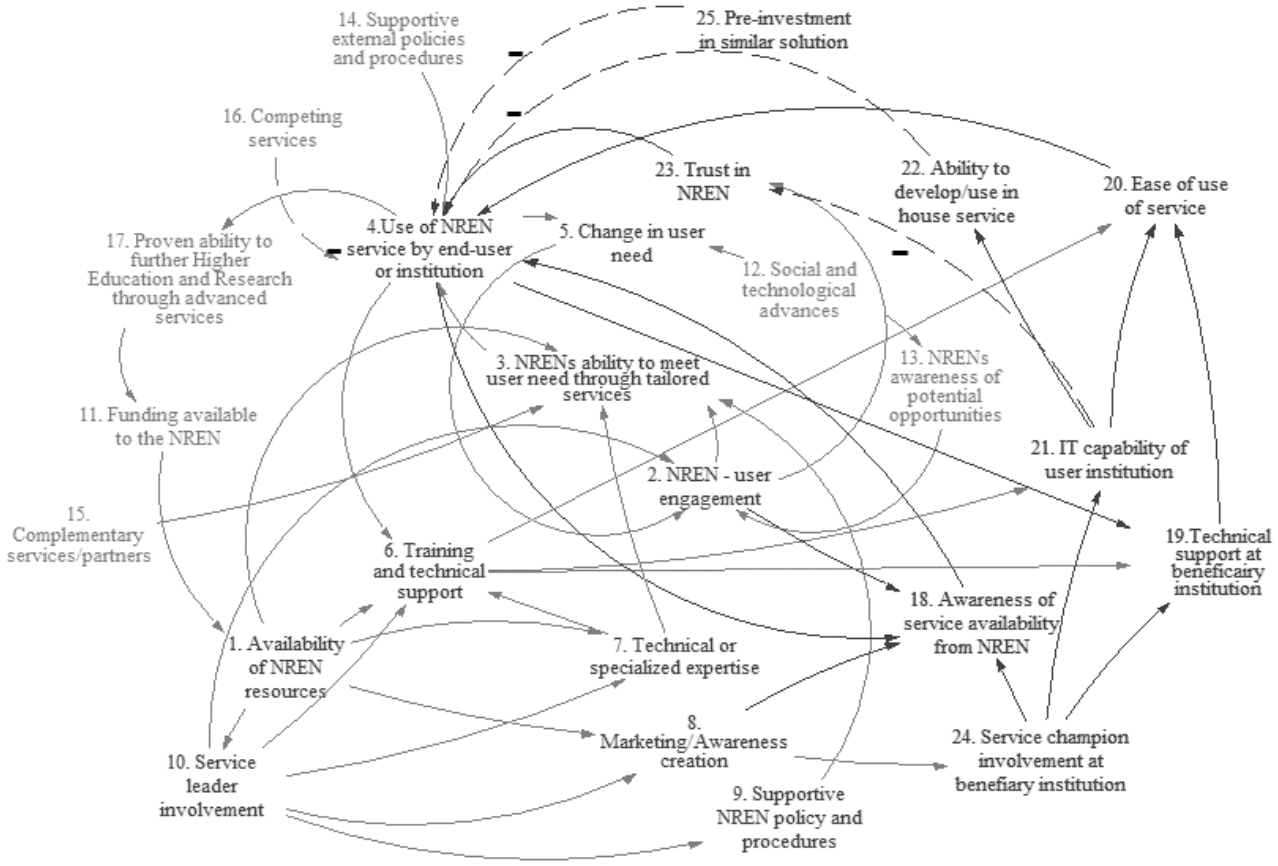

Fig. 1. Causal diagram representing significant factors and relationships (within the NREN, at the beneficiary institution and externally) that influence the adoption of NREN services to its beneficiaries. (Refer to original study on details of how the model was developed and color-coded.)

III. Research Aim

The aim of the research was to construct a shared mental model of the NREN services adoption context, using a systems thinking approach and refining and validating the model with experts.

The research objectives were formulated as follows:

1. Determine significant factors and relationships that influence the adoption of NREN services by its beneficiaries:
   - within the NREN
   - at the beneficiary institution and
   - externally.
2. Represent these factors and relationships in a meaningful way that will enable a shared understanding and mental model for stakeholders to reflect on, for optimization and decision-making.
3. Validate and refine the model by assessing the factors and relationships and their strengths with experts in the field.

This research paper begins with the background of the study and presents the results of Objectives 1 and 2, a model in the form of a causal diagram[2] presented in Fig. 1. It shows a static representation of the designed artifact, representing a NREN, beneficiary and external factors that influence the adoption of advanced services. A total of 25 factors are represented including their interrelationships, where solid arrows represent a positive relationship from one factor to the other and a dotted line with a minus ("-") sign shows a negative relationship from one factor to the other.

The paper then shows how Objective 3 was conducted, and presents results and conclusions drawn. This paper forms part of a larger research study.

IV. Research Paradigms

The research to achieve Objectives 1 and 2 was conducted in line with the constructivist/interpretivist paradigm, which grew from the philosophy of Edmund Husserl's phenomenology and self-awareness, and Wilhelm Dilthey and other German philosophers' studies of interpretive understanding called hermeneutics [14]–[18]. This entails knowledge being created cognitively by reflecting on existing knowledge and is, therefore, conducive to theory building [19]. Creswell and Creswell [20], who state that constructivists "generate or inductively develop a theory or pattern of meanings", confirm this.

As the research moves on to achieving Objectives 3, the study took on a more pragmatic paradigm approach, as the research aims to be more useful to practitioners.

[2] The term "causal diagram" is used instead of "causal loop diagram" (CLD), as reinforcing and balancing loops have not been labelled.

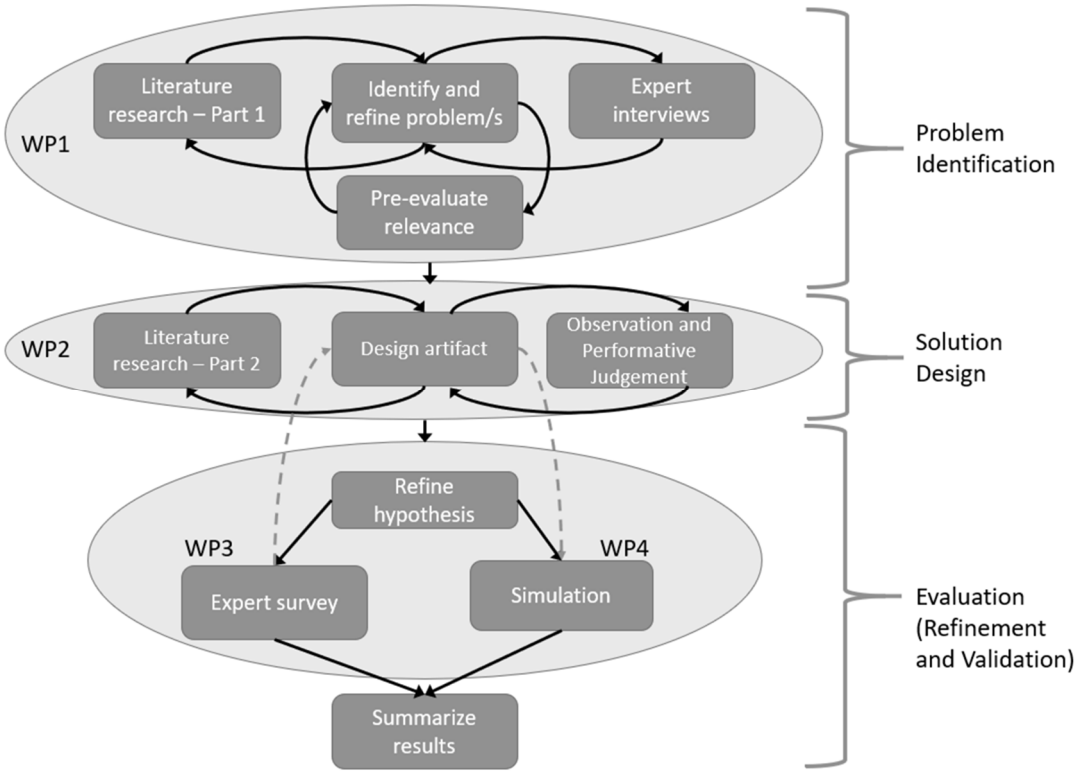

Fig. 2. A Design Science Research process divided into four Work Packages (WP 1-4). (Adapted from [38])

V. Theoretical Foundation

This research was guided by NREN service literature, adoption and diffusion theory, systems thinking literature and the studies which are mentioned below.

The NREN literature that contributed to the development of the model was largely in the form of NREN presentations and practitioner notes [1] [2] [21] [22] [9] and some academic documents [5] [11]–[13] [23].

Many existing NREN models are specifically designed for the country in which it was developed and it is consequently difficult to say how relevant the models are to other NREN contexts. The models are also usually linear in their approach. Therefore, this study aims to develop a shared model by using a non-linear approach, such as systems thinking, and taking into account inputs from experts across multiple NRENs which is novel to this context.

The developed model (Fig. 1) was also guided by Roger's Diffusion of Innovations Theory [24] and the Technology-Organization-Environmental framework [25].

A. Systems thinking

A systems thinking approach considers a holistic view of how parts of a system influence and interact with one another over a period of time, to facilitate a shared understanding of how the system works. Using tools such as causal diagrams to represent a system, helps to develop a shared mental model and understanding of how aspects of the system will unfold over time. It also helps to visualize the web of interconnectedness of factors and forces at play.

Systems thinking has as its primary purpose the enhancement of management practices [26]. Jackson [27]who is an authority on different streams of systems thinking and their origins, highlights the three traditional applied systems thinking (AST) approaches as "functionalist AST", "structuralist AST" and "interpretivist AST" [27].

Under the "interpretivist AST" are the soft systems approaches of Ackoff [28], Churchman [29] and Checkland [30]. These approaches are labelled 'interpretivist AST' because instead of trying to build systems models of the world they seek to work with different interpretations of reality. Checkland [31] puts this succinctly in stating that soft systems methodology shifts "…systematically from the world to the process of enquiry into the world." Jackson states that "Just as at the level of tools, the complexity, heterogeneity and turbulence of problem situations, requires that systems practitioners operate in a pluralistic manner, using different methodologies based upon alternative paradigms. We should seek to benefit from what each has to offer. Critical systems thinking can provide its greatest benefits only in the context of paradigm diversity" [32].

This study therefore uses an interpretivist AST approach, but will incorporate multiple paradigms and mixed methodologies.

The model developed can later be converted into a systems dynamics model to investigate complex, multiple-loop non-linear systems [33].

B. Similar studies

Two specific research studies were followed closely in this research. The first study by Hossain [34] modelled factors that affect the ICT adoption in three schools in the United Kingdom.

The second study, by Fanta [16], analyzed the system dynamics from the "Acceptance stage to Sustainability of eHealth Systems in Resource Constrained Environments (Ethiopia)."

Both these studies have worked towards developing a shared mental model of their specific environment being studied. They then take their analysis a step further by creating dynamic simulations of scenarios that could occur, to validate the model and anticipate ways to manage, control and optimize the system.

VI. Research Method

A Design Science Research (DSR) method was identified as suitable in the larger research study. As explained by Barab and Squire [35], Design Experimentation or Design-based Research can be frequently traced back to Brown [36] and Collins [37], but there is debate around what constitutes design-based research. There is some agreement that the process involves "systematic engineering" and an iterative approach to create an artifact [35] [38]. The DSR method guidelines presented by Offermann et al. [38] were used. These guidelines were seen as appropriate as it provided a well thought-out and systematic approach to address the research problem and was created in an attempt to provide a standardized approach to design-based research methodology.

Offermann et al. [38] present a DSR method in four separate work packages that provide guidance on how to do DSR - from validating the relevance of the problem under investigation, to proposing an iterative method for artifact design, and suggesting how one can evaluate the artifact that is created. Fig. 2 was adapted from [38] for this research. This research paper presents the designed model (Fig.1 – a result of WP2 shown in Fig. 2) and a refined model (Fig. 3 – a result of WP3 shown in Fig. 2), which involved the use of an expert survey to validate and refine the model developed.

A. Expert survey

A questionnaire divided into four sections, was developed for participation by identified NREN services management experts. It was designed to take approximately 40 minutes to complete in one sitting.

Section 1 requested consent and assessed the experience level of the participant. In Section 2, an mp4 video, describing the model, was played for participants.. The causal diagram in Fig. 1 was narrated to the experts in a storytelling approach advocated by Bellinger [39] and in [40]. The model was unfolded in a story-like fashion, to enable participants to gain a better understanding of what the model represents, and the relationships presented. The participants were asked questions to assess their thoughts on the model to be representative of their specific NREN context as well as a typical NREN services context.

Section 3 concerned the validation and allocation of strength values to each of the one-to-one relationships in Fig. 1. Given that experts find it easier to express their beliefs using linguistic terminology, the choices in the questionnaire were presented as linguistic terms, similar to those used by Hossain and Brooks [41]. The format of the questions asked was:

"Factor X" will have [Select a response: a no/a small/a moderate/a big/a very big] increase on factor "Factor Y".

It asks if Factor X would have `no', a `small', `moderate', 'big' or `very big' effect on Factor Y. Each response would be mapped to a value and would be used to refine the diagram, resulting in the Fuzzy Cognitive Map (FCM) [42] in Fig. 3.

Section 4 was optional and provided participants an opportunity for additional comments.

The questionnaire was a combination of open-ended narrative enquiry type questions and questions which elicit a structured response that could be assessed quantitatively.

B. Choice of participants

There are over 100 NRENS worldwide with 33 in Africa as of March 2017 [43]. Purposeful sampling was used to select participants using an expert sampling technique. Experts who were determined to be appropriate for the study had one or more of the following attributes: contributed to NREN services management literature, contributed to NREN service management workgroups or were familiar with NREN service adoption processes. The experts selected were from a diverse group of NRENs. The sample size was selected to be large enough to sufficiently draw conclusions about the model. Theoretical saturation is often used as a guideline for designing qualitative research, with practical research illustrating that samples of 12 may suffice in cases where data saturation occurs among a relatively homogeneous population [44]. This mixed-method research has a significant initial qualitative portion that is required to validate the designed artifact, and the population was regarded to be relatively homogeneous as all participants were NREN service management experts. The researcher, therefore, aimed for a sample size of 12, in line with the theoretical saturation sample size.

VII. Results and Discussion

Results gained from the questionnaire were assessed using both quantitative and qualitative methods. In the qualitative responses, the researcher looked for agreement or disagreement with the designed model and selected specific responses that provided information to refine the model.

The results of Section 3 of the questionnaire were assessed quantitatively for each individual and as a combined group of experts with weighted responses defining each relationship represented in Fig. 1. In line with commonly used relationship weighting values for FCMs which range between 0 and 1 and by drawing upon the conversion values used by Tsadiras, et al. [45] and in [41], the conversion measures seen in Table 1 below were used to create a matrix representing each expert's unique responses.

TABLE 1: FUZZY CONVERSION MEASURES FOR RELATIONSHIP WEIGHTINGS

Fuzzy linguistic terms	no	small	moderate	big	very big
Fuzzy numerical weights	0	0.25	0.5	0.75	1

The weighting of experts' responses was determined according to their level of expertise (determined by asking the experts to assess their confidence in their level of experience in NREN service management processes).

Each expert's FCM was additively superimposed, using the following equation [46] [47]:

$$F = \sum_{i=1}^{n} W_i F_i \quad (1)$$

where F_i represents the augmented FCM matrix of responses for expert/stakeholder i. n is equal to the number of experts/stakeholders. W_i is equal to the credibility weight of expert/stakeholder i. This process cancels out combined conflicting opinions.

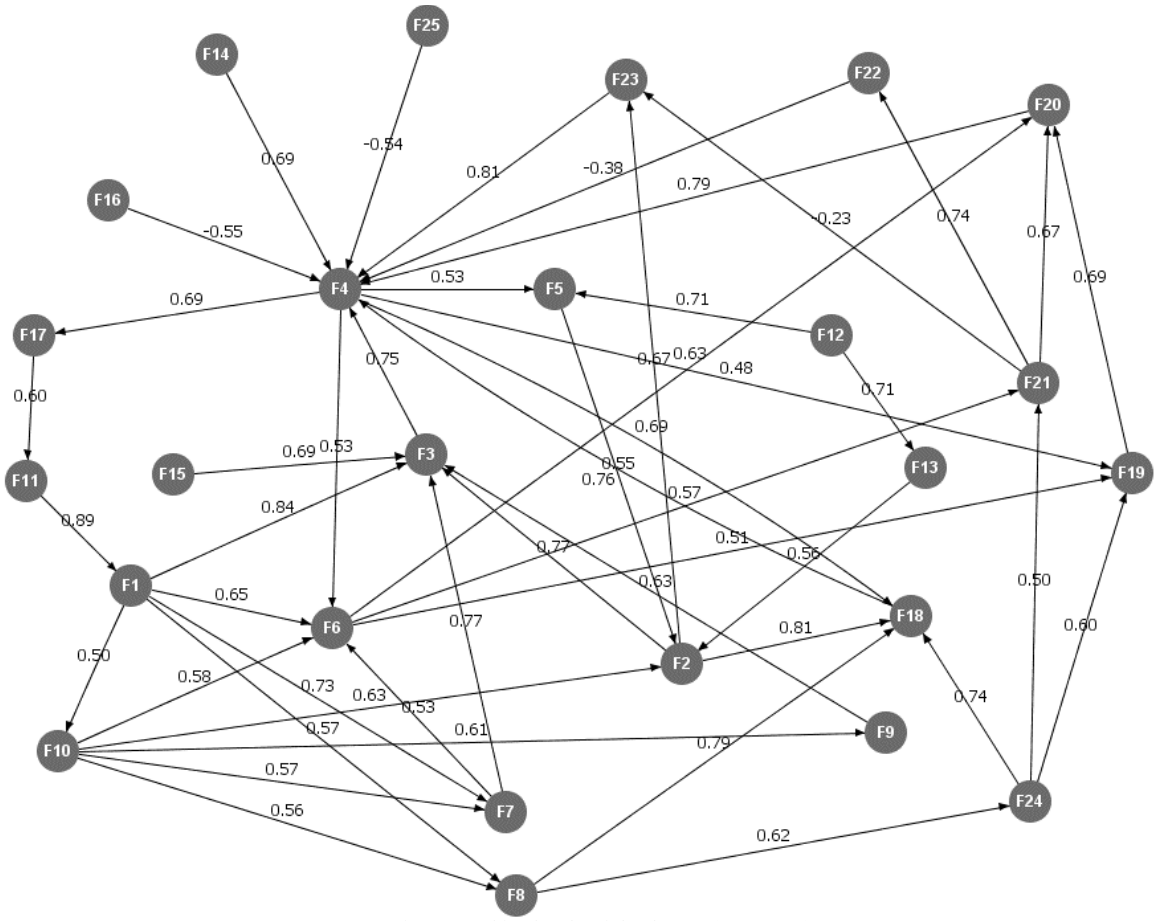

Fig. 3. Combined and weighted FCM (14 experts)

Assigning these quantitative values to the causal diagrams refined the model and enabled the model to be converted to an FCM introduced by Kosko [42] in which the strengths of the relationships in the initial causal diagram are more accurately defined. The resulting FCM is shown in Fig. 3 where the factors from Fig. 1 are represented by F1–F25 and the relationships between the factors are weighted. The study respondents included participants from 10 NRENs/countries as indicated in Table 2.

TABLE 2 : CODING OF PARTICIPANTS

Participant	NREN	Country
Expert 1	SingAREN	Singapore
Expert 2	JISC	United Kingdom
Expert 3	SANReN	South Africa
Expert 4	RedIris	Spain
Expert 5	RENU	Uganda
Expert 6	TERNET	Tanzania
Expert 7	SANReN	South Africa
Expert 8	TENET	South Africa
Expert 9	KENET	Kenya
Expert 10	AARNET	Australia
Expert 11	RNP	Brazil
Expert 12	BCNET (partner to CANARIE)	Canada
Expert 13	Internet2	USA
Expert 14	TENET	South Africa

Two out of 14 participants “strongly agreed” and 12 out of 14 participants “agreed” that Fig. 1’s depiction of the NREN value-added services context leading to NREN service adoption made sense generally.

Two out of 14 participants “strongly agreed”, 9 out of 14 participants “agreed”, 1 participant was “unsure” and 2 “disagreed” that the model’s depiction of the NREN value-added services context, leading to NREN service adoption, made sense in their specific environment.

Twelve out of the 14 participants indicated that there was no strong misrepresentation of the NREN services adoption context.

As only two out of the 14 participants indicated that the model is “probably not” useful in explaining the NREN service context to NREN stakeholders – the main reason given being that it is too complex – the model can be determined to be useful as a communication tool for those that need to know this level of detail. There is, however, the possibility that it needs to be summarized further or background information provided to specific stakeholders so that they do not become overwhelmed by the information presented in the model.

Only two out of the 14 participants did not see potential for this model to be used as a decision-making tool. Therefore, it can be concluded that the model shows potential to be used as a decision-making tool.

VIII. CONCLUSION

This research is novel in investigating value-added services management in NRENs to develop a non-linear and shared model for the NREN services adoption context, with refinement and validation from experts from international NRENs.

This research has contributed towards the application of design science research methodology, as well as the advancement of mixed-methods research methodology and applies these methods and a systems thinking approach to a new context.

This research has made a practical contribution by developing and validating models that are able to be used in the NREN services management context as a discussion and communication tool to reflect on the factors and relationships that contribute towards value-added services adoption in NRENs. This was confirmed by the use of an expert survey.

Further work, will be conducted to simulate "what-if" scenarios using Fig. 3, to further assess its potential as a decision-making tool to facilitate NREN service adoption.

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