A processual model for the conceptualization of reliability concerns and its validation among design stakeholders for sustainability

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Abstract.
The discourse addresses the different ways reliability information is communicated and shared to achieve sustainability at the early stage of product development, by conceptualizing the reliability communications process using a processual model. The model which is based on a mechanistic and a systemic view is used for analyzing the reliability information and concerns shared and communicated between and among design stakeholders. To prevent unauthorized persons from gaining access to the reliability information during the product design stage, an information filtering system is included in the model. The conceptualized processual model is a piece of a more extensive undertaking that aims at assessing the sustainability of the different communication scheme among designers and product reliability teams located at different geographical sites provide a platform for rethinking the product reliability concerns and sharing. The model has been validated using an expert-opinion based method.

Keywords: Conceptualization of Reliability; Reliability information and concerns; Communications; Processual model; Early design stage; Delphi.

1. Introduction
In designing complex engineering products like cranes or a jet engine, there is a general view, that to obtain a sustainable design that is free of reliability related issues, a series of decisions must be made and communicated between the involved stakeholders; designers and the reliability team [1-7]. Who may be located at different geographical sites or work for different companies. The communications of product design and reliability concerns are critical for the success or failure in a new product development process [8, 9]. Are understand to be a complex technical and social process that enables the sharing and circulation of technical and intelligent-based knowledge of the design product and the management of their reliability concerns [10], as well as for the product development resources and capabilities [11]. Although, some efforts have been made in the study of product design communication as reflected in the literature by [12, 14]. The way reliability concerns are communicated among design staffs at the early design stage is still an open area for a research study [15]. There is the need for design stakeholders and their companies as the case may be, to comprehend the web of interconnected communications, so as to fulfil configuration time constraints and to accomplish organizations' unwavering quality target at a reduced cost.

In this paper, a conceptualized processual model for communicating reliability information and concerns at the early design stage is proposed. The conceptualized model which is a piece of a more extensive undertaking that aims at assessing the different communication situation among designers and product reliability team/experts located in the same or at different
geographical sites provides a better platform for rethinking the communication of reliable information at the early design stage [16, 17].

2. Reliability communication process
The internal and external reliability communications which can be described as the communication between and among design, stakeholder located in the same geographical location. This is said to be critical for sharing and circulation of technical and intelligent-based knowledge and reliable information for the achievement of a sustainable design [18].

The different sources of product reliability information have been extensively studied [19]. It is worth mentioning here that, the communication of the reliability information and concerns through the internal and the external chain of product design, stakeholder at the early product design phase can lead to high-performance design and manufacturing [20]. The implication of this type of communication chain is that there must be a process of analyzing the reliability of information and concerns that are shared and circulated to the different design stakeholder. Hence the information and concerns are expected to be shared and communicated on a basis of the managerial level of the stakeholder and depending on the role of the stakeholder by making the information and concerns go through an automated information filtering system.

Analyzing the reliability information and concerns shared and circulated among the different design, stakeholder within and outside the different geographical site is a complex decision-making process. This can be achieved by studying and integrating the strategic vision and perspective of the parent design company and that of the other involved stakeholders and companies to avoid any potential conflicts of interest. This further enabled the capacity and capabilities of a systematic perspective communication process analysis [21]. Although a very limited body of literature has explored this method.

Another method used in analyzing the reliability information and concerns shared can be through a critical assessment of the technical, social, ethical, economic, political and competitive stances and content of the reliability information and concerns being shared [22]. This is important as it will prevent the sharing of sensitive information that may not be meant for some members of the team/chain.

2.1 The strength of the processual reliability communication model
The term processual in this paper, if considered in a broad sense, covers the process of sharing reliability information and concerns in all relevant managerial levels in an organization. The proposed processual reliability communication model is a powerful tool for supporting product design and for preventing early/infant product failure. In designing the model, a careful and elaborate research was performed both on the mechanistic and systematic view/approach proposed for the model. Furthermore, the possible problem areas in the communication and sharing of the reliability information and concerns were also considered and accounted for in the model. The key main problem areas include; (1) information, interpretation, (2) understanding the interpreted information, (3) data and information handling and (4) system logic [23]. Early/infant product failure is costly and in most cases very difficult to change. The difficulty in most cases does not lie generally on the generation of new designs when one fails, but on the assessment and reporting of the actual reliability concerns in the failed product. The selection of the reliability concerns that worth considering by the design stakeholders and the design stakeholders that need to have access to such sensitive information.

In addressing these concerns, a processual reliability communication model with an information filtering system has been proposed in this study; also a multi-criteria decision-making method is recommended for the assessment of the reliability concerns. If this approach
3. Methodology

3.1 Conceptual processual model for communicating reliability concerns

The formation of the processual model for the communication and sharing of reliability information and concerns at the early design stage is considered a vital ingredient for achieving a sustainable design. Although several research studies have reported different techniques for sharing and transmitting information generally in organizations, like the use of video conferencing, etc., which usually takes a reductionist view, where the sharing of information is regarded as a process solely for conveying information from the source to the receiver with no concerns if the receiver understands the information passed.

In this study, however, the sharing and communication of reliability concerns at the early design stage are reported from two perspectives, from the internal and external reliability communications quadrant using a distributed network which is based on a mechanistic view and systemic view. The use of a mechanistic view of the proposed distributed network is mainly to gain and include the five mechanistic elements of communication which includes the source, transmitter, channel, receiver, and destination [24]. The elements are implemented in the proposed model as follows:

1. The information from the source produces the message,
2. The message is encoded into a signal and then transmitted,
3. The transmitted signal is passed through and across a channel to the receiver,
4. The receiver decodes the signal,
5. The information is sent to the place (where the message is used).

The main advantage and implication of using the mechanistic view in the proposed distributed network are that the technicalities in the reliability information and concerns can easily be transmitted to the right persons, irrespective of the quadrant they belong (internal and external) without any interference.

The systematic view in the proposed model network is about communication and information sharing that is centred on content and relationship, where the ‘content’ referred to what is actually said (i.e. creating the meaning of the information). And the ‘relationship’ describes how it is said (i.e. the process) [24]. The systematic view elements used in the model include; (1) Data, (2) Statement and (3) Comprehension, [25]. Unlike the mechanistic view and approach, it adds the aspect of creating the meaning of the information passed, deals with the form (mode and media) of transmitting the information (utterance) and the aspect of understanding the distinction between the meaning of the information passed and the utterance. The technicalities in the reliability information and concerns need to be understood by the actual end user (destination) which in this case is referred to the internal and external design stakeholders. With the coding and encoding of the signal in the mechanistic view, the information shared is restricted, and the stakeholders within a particular managerial level that needs to have access to such information are the only ones allowed or trained to encode the signal in the network. To further prevent unauthorized persons from gaining access to the reliability information, an information filtering system is added to the network. The automated message filtering system restricts unwanted information from getting to the end user. The
A conceptual processual model for the communication and sharing of reliability information and concerns at the early design stage is shown in Figure 1.

Figure 1: A conceptual processual model for the sharing of reliability information and concerns

3.2 Validation of the model

In order to validate the proposed conceptual processual model for communicating reliability at the early product design stage, an expert consensus-based approach has been adopted. The result of the expert consensus-based assessment which focuses on the most important and salient finding in the study is used to prove the rationality, validity and feasibility of the proposed model for use in reliability communication at the early product design stage.

Study design: The process of validating the conceptual processual model is divided into four phases which include; a brainstorming stage - where the features of the model are discussed by a team of academics with specialties in product development, reliability management, and information sharing and communication. The brainstorming stage which is aimed at generating new ideas that are not in the original model presented provides the opportunity to rethink the whole essence of the model.

This stage is followed by consulting a wider group expert in the industrial sector to contribute or make their input into the design and formation of the model based on the idea generated
from the brainstorming stage. Next, the model is refined or fine-tuned in line with the suggestions and inputs from the experts. Finally, a check phase is introduced to validate and confirm the model based on the consensus opinions of the experts.

**Participant:** To ensure the best hands are used for the validation of the model, a purposeful expert selection approach has been adopted based on the suggestion in (Adeleke et al., 2018) [25] for the brainstorming stage. The purposeful expert selection approach allows experts with the right expertise and experience (Three (3) Senior Lecturers and two (2) Professors) to contribute new ideas for the formation of the model. The experts which were drawn from three (3) Federal Universities in Nigeria are believed to have the required experience and expertise to make meaningful input in the model formation. The brainstorming process which took about three (3) to be completed, was performed in the different offices of the participants. The different opinions and suggestions were recorded after proper permission was given. For the second stage, 64 copies of a questionnaire were sent to 30 international companies with research and development roles in Lagos, while another 30 copies were sent to 6 local product development firms around Ota in Ogun Nigeria.

**Data Analysis:** The result obtained from the brainstorming exercise based on the experience and expertise of the selected academic experts, were used for drafting the model that was passed to the industry experts that validate the model. The data stand as the first and a starting point for the conceptual-procedural model discussion phase. The discussion which took place multiple times via face to face interview and discussion addresses the way reliability information is communicated during the early design stage. The interview questions were structured around the following; (1) Is the form of the procedural model clear, coincide and correct? (2) Do you agree with the concept, the parameters, and information flow? And (3) are there any specific feature/ parameter missing in the model?

The result of the experts was recorded and was later transcribed verbatim and then coded according to the content analysis method [26] after permission was given. Although the experts all agreed with the concept of the model and its clarity, conciseness, and correctness, however, they recommended the addition of an information filtering system in the model, restrict, and control the information been passed or shared among the internal and external stakeholders.

The input included in the model as shown in Figure 1 above, with the improvement in the model, a questionnaire was sent to the industry experts and the questions were structured around, clarity in the form of the processual model, conciseness and its correctness, also the concept and information flow were included.

In the end, 91 out of the 94 questionnaires that were sent returned and were sufficiently completed, making a response rate of approximately 100 percent of the international companies with research and development roles in Nigeria, and 87 percent for the local product development firms. The overall response rate can be approximated to 93.33 percent, which can be considered large enough to establish a representative and credible data for analysis [27].

Using the Delphi method, a consensus was reached/obtained for the questions in the first round. After more than 80% of the experts, confirm/agree to the clarity, conciseness, and correctness in the formation of the conceptual-procedural model for sharing of reliability information, as well as the concept and information flow in the model. The questionnaire which has a total of 20 questions relating to the subject of the research is presented in Appendix. For each of the question, the experts were asked to choose the answer on a scale between 1 and 5 where 1= not really clear or not really sure, 2= not clear or not sure, 3= clear or sure, 4= very clear or very sure and 5= really very clear or really very sure.
Furthermore, the collected data are analysed using a Single-factor ANOVA statistical method. The results of the analysis which have been presented in Table 1 and 2 below shows that the calculated F-value is greater than the F-crit \(i.e. (3.347 > 1.592)\), hence the features and model attributes are considered significant and supports the proposed conceptual processual model. The result can also be interpreted as statistically significant since the significance value (\(P\)-value =0.000) is less than the significance level 0.05 which is denoted as \(\alpha = 0.05\).

| Groups | Count | Sum | Average | Variance |
|--------|-------|-----|---------|----------|
| Q1     | 3     | 158 | 1.756   | 0.771    |
| Q2     | 1     | 191 | 2.122   | 0.805    |
| Q3     | 2     | 215 | 2.389   | 0.757    |
| Q4     | 1     | 201 | 2.233   | 0.833    |
| Q5     | 3     | 203 | 2.256   | 1.001    |
| Q6     | 2     | 202 | 2.444   | 0.749    |
| Q7     | 1     | 192 | 2.133   | 0.948    |
| Q8     | 1     | 234 | 2.600   | 1.164    |
| Q9     | 1     | 179 | 1.989   | 1.022    |
| Q10    | 2     | 206 | 2.289   | 0.814    |
| Q11    | 1     | 187 | 2.078   | 0.949    |
| Q12    | 1     | 190 | 2.111   | 0.931    |
| Q13    | 2     | 197 | 2.189   | 1.211    |
| Q14    | 3     | 216 | 2.400   | 0.512    |
| Q15    | 2     | 179 | 1.989   | 0.932    |
| Q16    | 3     | 205 | 2.278   | 0.967    |
| Q17    | 1     | 190 | 2.111   | 0.886    |
| Q18    | 3     | 197 | 2.189   | 0.739    |
| Q19    | 2     | 208 | 2.311   | 0.689    |
| Q20    | 2     | 210 | 2.333   | 0.697    |

| Source of Variation | SS    | Df    | MS     | F      | P-value | F crit |
|---------------------|-------|-------|--------|--------|---------|--------|
| Between Groups      | 55.267| 19.000| 2.909  | 3.347  | 0.000   | 1.592  |
| Within Groups       | 1546.733| 1780.000| 0.869  |        |         |        |
| Total               | 1602.000| 1799.000|        |        |         |        |

Finally, in following the validation phase proposed above, the entire participants were sent the final structure of the model for review. All the experts responded with no content related issue identify since their earlier suggestion have been added.

4. Conclusion
In this paper, a conceptualized processual model for communicating reliability information and concerns at the early design stage has been proposed. The model which is based on a
mechanistic and a systemic view/approaches is used in analyzing the reliability information and concerns shared and communicated between and among the design stakeholders within and in different geographical sites working for the same or for different companies.

The conceptualized processual model combined the five mechanistic elements of communication which includes the source, transmitter, channel, receiver, and destination with the systematic view elements which include; Information, Utterance and Understanding to form a novel conceptualized processual model that is capable of sharing, circulating and restricting information depending on the managerial level or role of the receiver (designer). To prevent unauthorized persons from gaining access to the reliability information stream, an information filtering system is added to the model. The conceptualized processual model for communicating reliability information and concerns is aimed at providing the different communication situation among designers and product reliability teams and experts located at different geographical sites and provide a platform for rethinking the product reliability concerns and sharing. To prove the rationality and feasibility of the model, data have been presented that validates the model; this was achieved by means of an expert opinion-based approach. The collected that which was analysed using the Delphi method, confirm a consensus for the questions in the first round. After more than 80% of the experts, confirm/agree to the clarity, conciseness, and correctness in the formation of the conceptual-procedural model for sharing of reliability information, as well as the concept and information flow in the model. Furthermore, the collected data was analysed using a Single-factor ANOVA statistical method. The result of the analysis calculated F-value was greater than the F-crit i.e. $(3.347451 > 1.592361)$, hence the features and model attributes can be interpreted as significant and supports the proposed conceptual processual model. In the future, the features of the model will be used in designing a communication network and software.

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