

SOURCES OF CRITICAL SITUATIONS AS CRUCIAL ACTIONS IN DESIGN

S. L. da Silva Vieira, P. Badke-Schaub, T. M. Fonseca and A. A. Fernandes

Keywords: sources, critical situations, crucial actions in design

1. Introduction

The fundamentals of this research rely on the need to study designers' behavior to improve designers' performance. The research places in perspective the concepts of the Lean Thinking (LT) as dimensions to study designers behavior in different design disciplines. In this study, the situation of *Muda* (LT central concept) is seen as sources of critical situations, that can limit but can also increase designers' behaviour and performance if the appropriate measures are taken.

On daily basis designers' have the chore to keep one's countenance facing complex and uncertain situations with the consequences of several drawbacks, delays, conflicts but also constructive outcomes. Though designers might be experienced they are not always prepared to cope with these situations in an appropriate manner. Designers can miss their orientation, what finally might lead to less efficient and less effective performance. Such situations require crucial decisions to avoid or to be able to cope with its downside effects and to seize opportunities and constructive outcomes.

Inherent to the occurrence of such crucial instances is the risk to diminish designers' input of value for the creation of design results. Designers play an important role in the creation of value in the objects, products, systems and surroundings of everyday life to be left without awareness regarding these situations.

Little attention has been placed to such design management issues on an empirical basis. The study of the phenomenon of these situations has not been appropriately addressed in design methodology. The present paper presents a transdisciplinary study across five design disciplines on the sources of critical situations and its crucial actions in designing.

2. Background

The research places in perspective the most important concepts of the Lean Management philosophy [Womack et al. 2003] as dimensions to study designers behavior across design disciplines. Lean Thinking (LT) is about identifying the pathologies of the processes and support to cope with such causes and effects. LT is a non-discipline related framework grounded in specific principles that sustain a transdisciplinary approach. However there are also obstacles to be aware of:

- LT focuses on the customer and the producer as value creator, the designer is not referred to. Though, the designer plays an important role in value definition, especially in the early phases of product development.
- The Lean terminology is related to the manufacturing environment. The direct application of LT in the design context would not be suitable as a shared language of communication.
- LT defines muda as negative phenomena. However the sources of the types of muda (any human activity which absorbs resources but creates no value) do not always lead to negative

effects but also to positive consequences. As example, a delay might be beneficial providing more time to accomplish another task.

In design, the situations of *muda*, and according to their influence on the process and designers behaviour are comparable to the notion of critical situations, as circumstances that have a crucial importance in the success or failure of something. Assuming that such effects can be positive or negative depending on the context and the results this research proposes a phenomenological approach to these situations in designing. As consequence we propose the conversion of the concepts of LT into dimensions that are suitable to understand designers' behaviour and their design processes in different design disciplines. In this research, value (LT principle) is seen as value delivery from the designers' point of view, in the context and interaction with other stakeholders. The situation of *muda* (LT central concept) is seen as sources of critical situations, that can limit but can also challenge designers' behaviour and performance. Therefore, value delivery and critical situations are in this research the drivers for a translation of the Lean philosophy in design research.

With such intuit, this work presents a transdisciplinary approach to the designing activity across five design disciplines namely, Graphic, Interaction and Industrial design, Architecture and Mechanical engineering. A case study based approach across the data collected in design consultancies gives ground to the identification of critical situations in design.

3. Critical situations in design methodology

The traditional prescriptive models in design methodology such as the Basic Design Cycle [Roozenburg and Eekels 1995] but also newer approaches such as the VIP approach [Hekkert and van Dijk 2001] share one common goal, they all aim to support the individual designer. However, designers have to face many situations with different sources of elicitations. Thus, design models do not represent the sources and possible effects of critical situations that designers might have to cope with as well coping actions to uphold performance. Several attempts to understand the principles that governed the behaviour of designers concerning the mental and physical processes [Cross 1996] have been critical and innumerable to improve design methodology. On the other stream, few attempts have been made to understand the sources of fruitless performance in designers' behaviour. Such contributions are sparse and focused in the downside aspects of specific and singular issues such as design fixation [Cardoso and Badke-Schaub 2009] stuckness [Sachs 1999] inappropriate focus of attention [Simon 1995].

General contributions to methodology and theory in design issues such as risk management [Jerrard and Barnes 2006], [Seering and Oehmen 2011] are in close proximity to the focus of this research. However such studies only represent features of a general framework that integrates the sources of critical situations, which go beyond the study of the phenomenon of risk.

Research on critical situations has its origins in psychology. The study of the profile of critical situations and its aspects gave origin to the method to identify critical incidents [Flanagan 1954]. In design research, such circumstances have been differently tackled, namely as decisive situations [Jones 1970], critical moves [Goldschmidt 1996], and critical situations [Frankenberger and Badke-Schaub 1998]. However, these contributions are confined to studies based on one single design discipline, just identify mechanisms to cope with downside effects and do not study the nature of the phenomenon sufficiently in depth so that its sources can be identified and its copying measures empirically based.

4. Research procedure

A case study based approach in five design disciplines gives ground to the exploratory research on critical situations. Data were assessed with field studies in design environments during periods of observation providing insights into designers' behavior (Table 1). Observation periods in four design consultancies and one group of students of Industrial design, provided the social context of the designing activity, and the opportunity to observe the critical situations of the daily life in design offices. The design consultancies are based on the disciplines of graphic and interaction design, architecture and engineering. The fifth case study analyses a graduation project of students in

Industrial design engineering. Data were assessed through observation of on going projects and interviews.

Table 1. Overview of meetings and interviews per case during the periods of observation

Source of data	Case study 1	Case study 2	Case study 3	Case study 4	Case study 5	Total
	Graphic design	Interaction design	Architecture	Engineering	Industrial design	
Interviews	9	23	9	9	5	55
Meetings	6	7	7	8	-	28
Observation period	6 weeks	4 weeks	4 weeks	5 months	3 weeks	

Results from the present study refer to data collected from interviews. Designers from several background activities answered a structured interview of open questions based on several topics regarding the designing activity such as, motivation, planning, management, teamwork and stakeholders among other aspects. A selection of 25 interviews, five per case study, was made based on the most descriptive and informative answers.

In case study 1 the five interviewees are all designers with background in graphic design with nuances in visual, communication, editorial and multimedia. In case study 2 the five interviewees have background in graphic, industrial and multimedia design and illustration. In case study 3 the five interviewees are all architects with special interest in the development of specific and dissimilar tasks. In case study 4 the five interviewees are all engineers with specific background in electronics, hardware, control, and mechanics. In case study 5 interviews were conducted with graduation students in Industrial design engineering.

5. Data analysis

Data were audio recorded for analysis. Iterative coding was done in the interviews transcripts in Atlas software (www.atlasti.com). The analysis of the interviews was based on the study of the statements describing occurrences, its nuances, multiple aspects and explanation inherent to each of the five design domains.

Influential situations brought into account were based in four sources of experiences: individual, teamwork, on the design subject, and external influences.

From a total of 581 utterances, two types of influential situations derived from the analysis of designers' statements:

- 217 Critical situations – where designers describe how the situation is recognized, its cause or antecedents and consequences leading to positive or negative outcomes and no solution is provided, only the analysis of the possible circumstances.
- 365 Crucial situations (critical situations with crucial actions)– where designers describe how the situation is recognized, identify its antecedents and consequences and foresee or recognise what has to be done for an effective result.

These situations do not just refer to an eminent success or failure of the design process or result, but to the effectiveness of the intended result and are many times discrete, thus unnoticed or disregarded. Therefore the importance of a permanent awareness. The influential situations fail to be noticed when they were never unexperienced, when they are new, when they are assumed as inherently solved, and when its core issue is yet not unveiled and the situation remains intransparent.

Critical situations and crucial actions have influence in the goal, direction, concept, detail, teamwork, planning and ideation towards the design result.

In a initial stage the Lean Thinking categorization system of types of muda [Womack et al. 2003] was used as a guiding framework in the analysis and clustering of these two groups of situations. Such approach to the analysis helped to see the advantages and disadvantages of the framework such as, the identification of other sources as categories and the limitations of the Lean terminology, namely in what concerns to the muda categories, inherently related to the manufacturing environment, therefore unsuitable as a shared language in designing across domains. Additionally, the analysis of muda categories shown a prejudice, a negative connotation. For example, when looking for descriptions related to the muda category of 'waiting', such situations were not always seen as unhelpful. Many

times, designers refer to situations of waiting as helpful, creating space to think or even a necessary pause to proceed. Thus, the orientation of the analysis followed the search for the sources of situations that can bring a twofold outcome: a helpful or unhelpful influence.

Although dissimilar incidence and predominance characterized the particularities of each design discipline, invariant sources of critical situations were found across the interviewees' statements.

After several stages of analysis and discussion of the characteristics of the 581 utterances and with the intuit to reach a non-overlapping set of clusters a categorization system was fine-tuned. From the 365 utterances on crucial situations, a total of 391 crucial actions were identified. A particular characteristic emerged from the analysis while clustering sources of critical situations and sources of crucial actions. Both aspects led to the same categories.

6. Sources of critical situations and crucial actions in design

From the analysis of the interviews a framework of invariant types of sources of critical situations and crucial actions in design is depicted in seven categories as shown in Table 2. Aspects of the seven main categories are asserted and a positive and negative behaviour derived from these circumstances is exemplified. In the following the definitions per category are described.

Table 2. Sources of critical situations and crucial actions and examples of negative and positive behaviour

Critical situations and Crucial actions in design			
Sources	Challenges	Examples of observed successful behaviour	Examples of observed less successful behaviour
Dosage	Adequacy	Look for essential criteria	Missing criteria
	Balance	Make things matching	Over dosage
Planning	Probability	Preparedness	No probability evaluation
	Anticipation	Foreseeing opportunities	Overestimation of predictability
Framing	Orientation	Reflected choice	Difficulty to choose
	Focus of attention	Convergence	Stuckness
Ambiguity	Surprise	Opportunistic procedure	Missing opportunities
	Knowledge	Reflected analysis	Clients that do not know what they want
	Intransparency	Searching for indicators	Difficulty to grasp the features of a problem
Information Transfer	Communication	Transparent communication	Confirmation bias
	Exchange	Awareness of the need for sharing information	"Tunnel view"
	Documentation	Keeping record of sub-results	Not keeping record of sub-results
Interdependency	Interfaces	Awareness of the different interfaces involved	Acting without reference to others involved
	Suspension	Take time for decisions and keep in mind long and short term consequences	Missing feeling of competence
Envision	Open up solutions	Generating alternatives	Difficulty to think in the future

- Dosage - refers to the need to find adequacy (enough in quantity or good enough in quality for a particular purpose or need) or balance (emotional, economical, aesthetical, or negotiable stability) in the quantity and quality of different activities and measures, in order not to overdo or be underdone.
- Planning - refers to situations which need an action plan for the future regarding the extent to which something is probable (probability), and the extent to which something is expected or predictable and take action in order to be prepared (anticipation).
- Framing - refers to situations that hinder or provide orientation (direction to proceed) and focus (concentrating interest, to adapt or adjust so that things can be seen clearly), that need to be framed or reframed.

- Ambiguity - refers to situations of surprise (denoting something made, done, or happening unexpectedly), intransparency (difficult to perceive or detect) and knowledge (what is known or not about facts, information, and skills acquired by a person through experience or education), which create a kind of ambiguity that can hinder the process but can also be beneficial to generate alternatives and overview.
- Information transfer – refers to situations where the transference of information requires to deal with different challenges such as communication (the successful conveying or sharing of information, ideas, feelings, news, through the means of sending or receiving information), exchange (an act of giving or doing something to somebody and receiving something in return) and documentation (the act on recording material that provides official information or evidence or that serves as a record).
- Interdependency – refers to situations that need to establish or undo interdependencies, through the creation and recognition of interfaces (a point or moment where two systems, subjects, organizations, etc., meet and interact, such as people, companies, expertise, technical limitations) or suspension (the action of suspending someone or something or the temporary prevention of something from continuing or being in force or effect).
- Envision - refers to situations that request to imagine future possibilities regarding the design goal, solution or sub-solutions, giving form to mental images or making something visible to the eyes. Such situations can hinder or further the design process regarding the extent to which such mental or physical images of solutions are created with flexibility, with no restrictions, providing a wider ideation space to be unfolded, and solutions to come into view.

All the sources of critical situations can be found in circumstances that make decisions vulnerable and do not intended side and long term effects. Therefore, being aware of crucial actions to cope with these circumstances is essential for practitioners, students and educators of designing.

6.1 Incidence of critical and crucial situations per category

From the analysis of the 581 utterances derived from the interviews, results on the incidence of critical situations per category are depicted in Figure 1. Results show that the second level categories of Interfaces, Focus of attention, Orientation and Adequacy show high incidence as sources of critical situations and therefore the need to cope with such circumstances.

As example, the antecedents of the critical situations regarding two of the categories with highest incidence are described. Antecedents of critical situations of *Interdependency* relate to the need to experiment design solutions dependent on the execution of others, such as in situations of outsourcing, on the choice or awareness of the persons that will act as interfaces with stakeholders, such as in contact with the client. Antecedents of critical situations of *Framing* relate to the need to structuring information, structuring what is wanted, to provide a clear vision of the design goal, framing strategies, framing the solution on what will remain, framing the core of the solution for a more structured and natural development, framing to eliminate superfluous things around the problem, reframing to reconsider unnoticed aspects, or aspects judge in a biased way, or framing to see the whole of the parts.

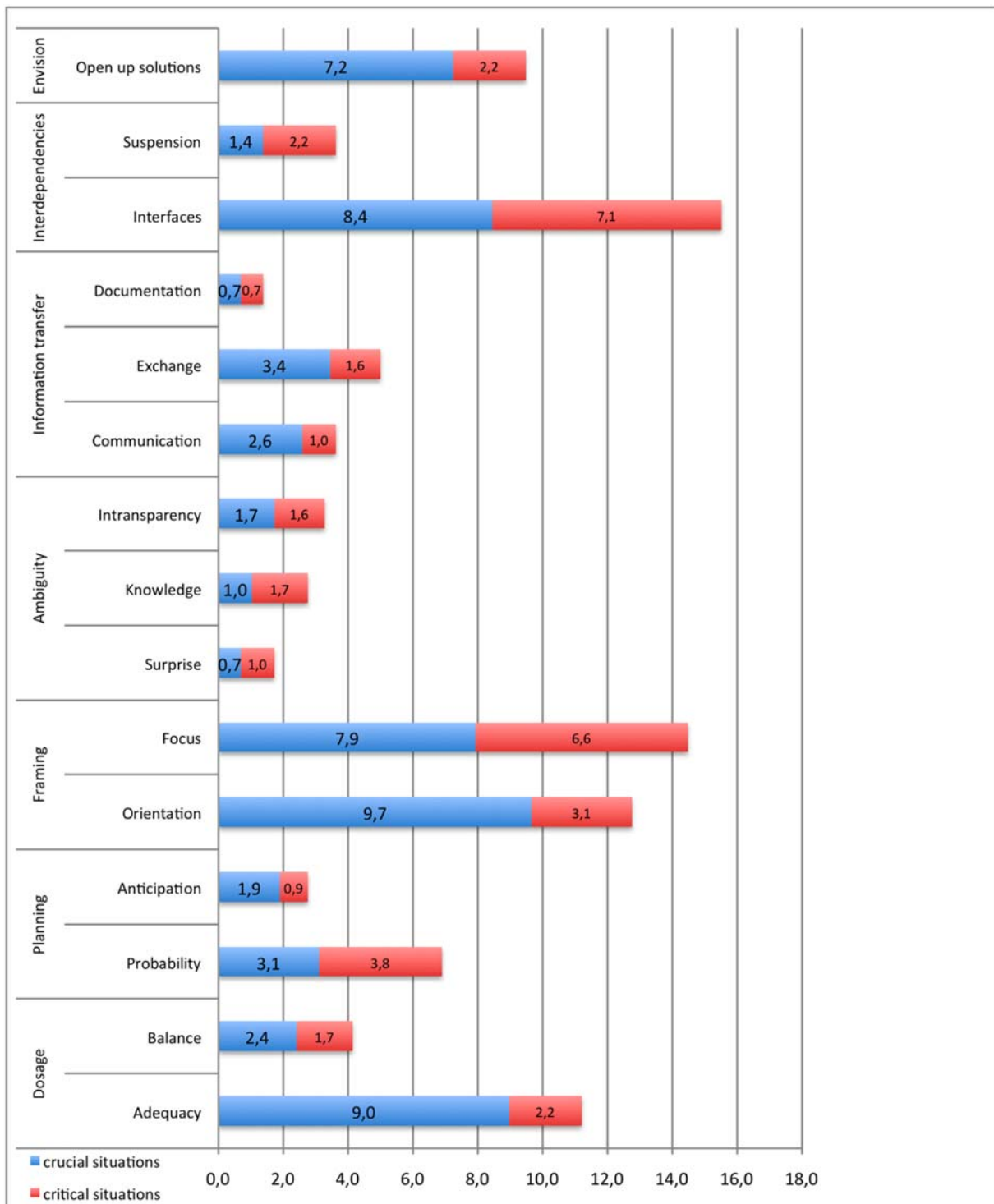


Figure 1. Relative % of the incidence of critical and crucial situations per category across the case studies

Results show that there is a percentage of critical situations without the description of coping actions across all the categories. The second level categories of *Interfaces* and *Focus of attention* show the highest incidence as sources of critical situations. Therefore results indicate the importance that a framework of awareness of critical situations and its crucial actions can have to improve performance in designing.

6.2 Incidence of crucial actions per category

From the analysis of the 365 utterances of crucial situations derived from the interviews, results on the incidence of crucial actions per category are depicted in Figure 2. Results show that the second level categories of *Exchange*, *Orientation* and *Balance* show high incidence of crucial actions and therefore known solutions to cope with influential circumstances.

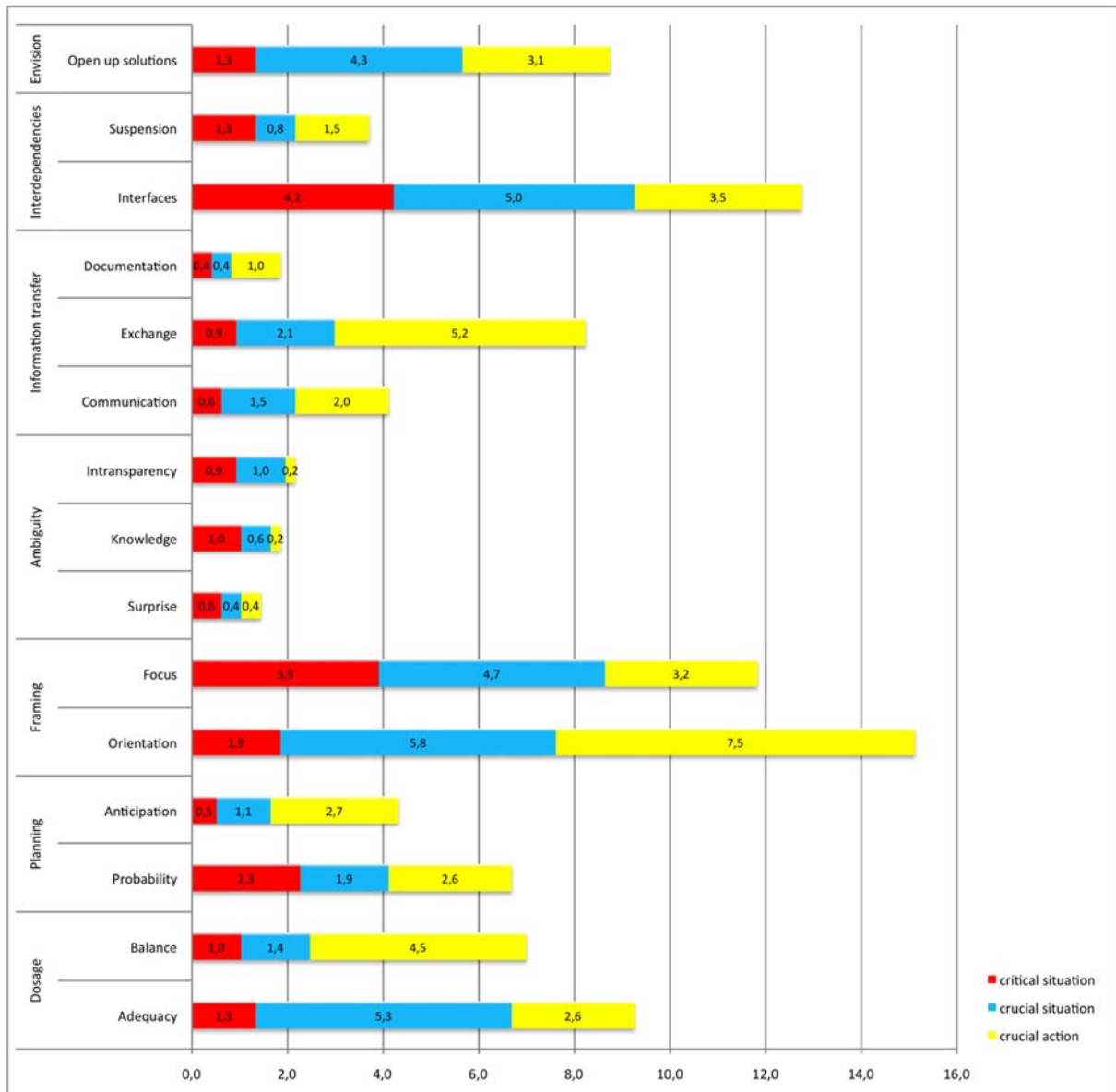


Figure 2. Relative % of the incidence of critical situations, crucial situations and crucial actions per category across the case studies

A total of 391 crucial actions were identified and coded according to its source. After several rounds of analysis and discussion a common categorization system was found. Figure 2 shows the relative frequency per sub-category as sources of critical and crucial situations (from a total of 581 utterances) as well as crucial actions (391 statements) in designing.

For example, the second level categories of *Suspension*, *Documentation*, *Communication*, *Anticipation* and *Probability*, have more incidence as crucial actions than sources of critical situations.

Due to the limited extension of the paper it is not possible to show how all the categories interact with each other as sources of critical situations or crucial actions. Table 3 shows dominant crucial actions to cope with sources of critical situations.

Table 3. Relative % of dominant crucial actions to each second level category of critical situations

Critical situations	Crucial actions					
Adequacy	Orientation	3,6	Focus	1,8	Open up solutions	1,8
Balance	Balance	1,0	Exchange	0,8	Adequacy	0,8
Probability	Anticipation	1,5	Orientation	0,8	Balance	0,8
Anticipation	Orientation	0,8	Probability	0,8	Open up solutions	0,5
Orientation	Balance	3,8	Exchange	2,8	Open up solutions	2,3
Focus	Orientation	4,9	Suspension	2,3	Interfaces	2,0
Surprise	Probability	0,3	Open up solutions	0,3	Communication	0,3
Knowledge	Orientation	1,5	Anticipation	1,0	Exchange	0,8
Intransparency	Exchange	0,5	Open up solutions	0,5	Interfaces	0,3
Communication	Exchange	3,6	Open up solutions	0,8	Focus	0,5
Exchange	Balance	1,3	Focus	1,0	Communication	1,0
Documentation	Communication	0,3	Orientation	0,3	Knowledge	0,3
Interfaces	Exchange	3,6	Orientation	2,8	Probability	2,3
Suspension	Probability	0,5	Focus	0,5	Suspension	0,5
Open up solutions	Orientation	2,0	Focus	2,0	Anticipation	1,0

6.3 Representation of the analysis

Knowing the incidence of critical, crucial situations and crucial actions per category was not sufficient to understand the mechanisms of influence described in the interviewees utterances. From the analysis of the statements, it was possible to infer the following patterns of sequence:

- Critical situations that are immediately perceived and the crucial action is known have direct solution.
- Critical situations that do not have a successful resolution might lead to other critical situations.
- Crucial actions that are not taken might lead to unsolvable critical situations.
- Crucial actions that are not taken, might be excessive or insufficient can lead to critical situations.

The representation of these patterns was done through the creation of a axial chart that shows the multidimensionality of the variables, of the above mentioned categorization system (Table 2).

Such chart derives from a function created in Wolfram Mathematica software, for the representation of the data analysis. This chart considers the same group of categories in axial dimensions with a cycle graph that illustrates the patterns of sequence. Each quadrant shows four stages of the patterns of sequence in the critical situations. The up right hand quadrant shows situations where immediate crucial actions are perceived and taken. The up left hand quadrant shows situations where the crucial actions were not taken, are insufficient or excessive. The lower left hand quadrant shows the consequent critical situations. The lower right hand quadrant shows situations where crucial actions can be taken to cope with the circumstances. Incidence of sequences are indicated in the chart. As an example, the following image (Figure 3) illustrates the sequences that derived from the utterances that relate to the category of *Information transfer*, second level category of *Documentation*.

In the up right hand quadrant it can be inferred that, *Documentation* is a crucial action to cope with critical situations that relate to *Knowledge*, *Orientation* and *Open up solutions*, as well *Communication* is a crucial action to cope with a critical situation regarding *Documentation*.

Situations where the crucial action of documentation is not taken, or is insufficient or excessive can lead to critical situations regarding, *Focus of attention*, *Intransparency*, *Communication* and unpleasant *Surprise*. On the other hand, *Adequacy* and *Orientation* are crucial actions to cope with such sequences of events. The up left hand quadrant shows the nature of the problem.

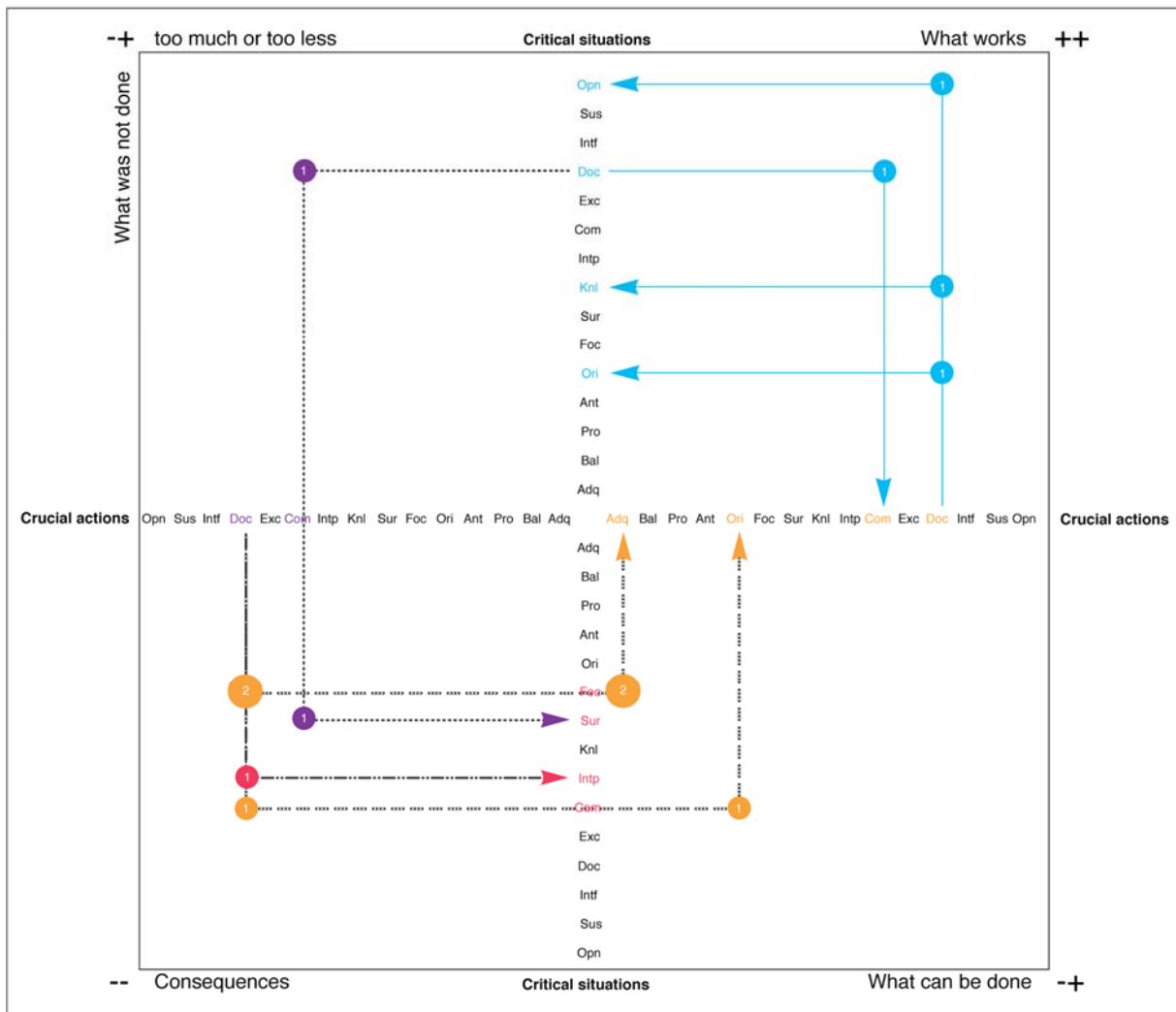


Figure 3. Flow chart illustrating the multidimensionality of the variables as sources of critical situations and counteractions in design. The chart refers to the representation of empirically based situations which source relate to the category of information transfer: documentation

7. Discussion

From the present study, invariant categories of sources of critical situations and crucial actions in design across five case studies are depicted. Results show that many of these categories ask for the development of empirically based actions to cope with sources of critical situations, avoid time consumption and uphold performance and motivation. In addition the study of the most incident patterns of how critical paths can happen can lead to the identification of crucial actions.

However, the importance of identifying unsuccessful paths leading to critical situations is not more important than the development of a framework of awareness of crucial actions in design that can be shared across and beyond the so called design domains.

As Francis Bacon phrased “*instantia crucis*” ‘crucial instance’ which he explained as a metaphor for a crux marking a crossroad, Isaac Newton and Boyle took up the metaphor in *experimentum crucis* ‘crucial experiment’, therefore a moment of decision and significance. With this framework of awareness of sources of critical situations and drivers for crucial actions in designing, the present research aims to contribute to increase designers performance in recognizing and facing crucial instances that ask for an action to be taken.

Another interesting result relates to the dissimilar incidence and predominance of these influential situations that characterize the particularities of each design discipline. However, the study of the

invariant sources of critical situations and crucial actions in design is prevailing in this study. However, an inference that derives from the present study is that the level of criticality of the situations depend of the design domain, for example as the operational component of a design result is fundamental in the domain of engineering and therefore situations where this is in question can indeed be considered as critical. In architecture, for example, the operability of the construction of a division being assured, does not mean that the intended result for that space is fulfilled. A larger or smaller window, or a lighter or vivid color in a wall might lead to more effective results without being critical regarding the functionality of the space. Therefore, these situations have a lower level of criticality and more of awareness to well being.

In addition, it seems to be relevant to Consider Christopher Jones (1970), remark that decisive situations are crucial to the definition of strategies, and conceptual change, therefore another path to follow in further studies.

8. Conclusion

From the present study, invariant categories of sources of critical situations and crucial actions in design across case studies in five design disciplines are depicted. A meta level of categorization of the phenomenon led to the identification of the sources, challenges, and actions to cope with such circumstances. The present results contribute to support design management with an integrative framework of awareness of sources of critical situations and counteractions in design.

Further studies based on the analysis of critical situations derived from the groups of meetings from the same case studies will provide the substantiation and expanded view of the present results.

Acknowledgement

The authors gratefully acknowledge Atelier Henrique Cayatte, João Álvaro Rocha Architects, Ydreams, the Delft Center for Systems and Control and the group of students from the Faculty of Industrial Design and Engineering of TuDelft for empirically support this research. The research reported is funded by FCT-Portuguese Foundation of Science and Technology, which is thankfully acknowledged.

References

- Cardoso, C., Badke-Schaub, P., "Idea fixation in design: The influence of pictures and words", *Proceedings of the International Conference on Research into Design, Bangalore, India, 2009*.
- Cross, N., Christiaans, H., Dorst, K., "Analyzing design activity". West Sussex, John Wiley and Sons, 1996.
- Frankenberger, E., Badke-Schaub, P., "Designers: the key to successful product development", Herbert Birkhofer (eds), 1998.
- Hekkert, P. van Dijk, M., "Designing from context: Foundations and Applications of the ViP approach", P. Lloyd and H. Christiaans, *Designing in Context, Design Thinking Research Symposium 5. Delft: DUP Science, 2001*.
- Jerrard, R., & Barnes, N. J., "Risk in design: Key issues from the literature", *The Design Journal, Vol 9, No.2., 2006, pp 25-38*.
- Oehmen, J., Seering, W., "Risk-driven design processes: balancing efficiency and resilience in product design", in Herbert Birkhofer (eds) *The future of design methodology, Springer, 2011, pp 47-54*.
- Roozenburg, N., Eekels, J., "Product Design: Fundamentals and Methods", Chichester, Wiley, 1995.
- Sachs, A., "Stuckness' in the design studio", *Design Studies, Vol.20, No 2, 1999, pp 195-209*.
- Simon, H., "Problem Forming, Problem Finding and Problem Solving", *Design and Systems, A. Collen, and W. Gasparski (eds.), 1995, pp 245-259*.
- Womack, J., Jones, D., Roos, D., "Lean Thinking. Banish Waste and Create Wealth in Your Corporation", New York, Simon & Schuster, 2003.

Sónia Liliana da Silva Vieira, MsC in Industrial Design
Architect, PhD candidate
IDMEC, University of Porto, Faculty of Industrial Design Engineering
Rua Roberto Frias, Porto, Portugal
Email: s.l.dasilvavieira@tudelft.nl
URL: <http://www.io.tudelft.nl/over-de-faculteit/persoonlijke-profielen/phds/silva-vieira-sl-da/>