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UDP-TRIZ model improvement with a focus group discussion of TRIZ experts

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Abstract. Universal Design is a fundamentals of good design. A product with Universal Design approach should provide wide range of solution for people with different purposes including those with diverse disabilities. However, designers often based on a subjective understanding of Universal Design Principles (UDP) to formulate design solutions. This result in the inaccurate conversion of design needs. A systematic approach is needed in order to develop a concept to meet the customer need. Previous studies shown potential integration of the Theory of Inventive Problem Solving (TRIZ) proposed to create a systematic approach for problem-solving requires creativity abilities. The purpose of this study is to explore the construction of the integration model of UDP and TRIZ 40 inventive principles. To construct the integration model of UDP and TRIZ 40 inventive principles, this study will use focus group discussion of certified TRIZ experts in the exploration of establishing an integration model of UDP and TRIZ 40 inventive principles. The further discussion onto the elements required to create the integration model by the TRIZ experts will be taken into consideration to construct a final model UDP-TRIZ model. Finally, the results are expected to lead towards a final integration model of the UDP and TRIZ integration model.

1. Introduction

In recent years, there has been an increasing interest in Universal Design for the disabled product**.**[1]. A study by Van der Linden (2016) [15] stated the main reason this limited adoption of universal design is unclear. This limited adaptation is influenced by the lack of appropriate information in the design approach, thus affecting the understanding of designers influencing the designer approach. Van der

Linden (2016) [15] conclude in the study that was focusing too much on universal design legislation discouraged the designer's creative process.

This hypothesis is supported by Ko [2], who stated conceptual design is a critical activity during the early phase of the product design process, where most creative ideas are generated within this process. Therefore, there is a need to develop a systematic universal design approach for this situation. One of the solution is the idea of integrating TRIZ with UDP approach proposed by Shahrin et al (2019) [3].

This paper presents the relationship between UDP and TRIZ 40 inventive principles. Each UDP is considered as an improving parameter, and each TRIZ 40 inventive principles is examined to fit the UDP. The relationship between corresponding TRIZ 40 inventive principles with UDP guidelines is identified by six Malaysia certified TRIZ experts.

2. Universal Design Principles

Universal Design, also known as "Inclusive Design" in the United Kingdom and "Design-for-All" in Europe, is not only a special requirement for the benefit of only a minority of the population [4], [5]. But it is a fundamental requirement of good design. However, in achieving universal design, there are significant drawbacks among designers. Designer's lack of experience and understanding of the condition of the disable people lead to inaccurate conversion in design needs [6] [15]. The purpose of the UDP is to embody the entirely concept of universal design. UDP provides an improved solution for people with diverse abilities. Universal Design Handbook has developed seven UDP[7]

Table 1. Universal Design Principle [7].

UDP1	Equitable Use
UDP2	Flexibility in Use
UDP3	Simple and Intuitive Use
UDP4	Perceptible Information
UDP5	Tolerance for Error
UDP6	Low Physical Effort
UDP7	Size and Space for Approach and Use

A set of guidelines for each UDP has been developed as a critical element that should be implemented in the design process. The primary purpose of this detailed guideline is to evaluate, guide and educate designers and consumers, focusing on the usability of a product or environment [7]. Detail guidelines for each UDP are shown in Table 2.

Table 2. UDP Guidelines [7].

Principle	Guideline
UDP1 Equitable Use	1a. All potential users could use this product in essentially the same way, regardless of differences in their abilities. 1b. Potential users could use this product without feeling segregated or stigmatized because of differences in personal capabilities. 1c. Potential users of this product have access to all features of privacy, security, and safety, regardless of personal capabilities. 1d. This product appeals to all potential users.
UDP2 Flexibility in Use	2a. Every potential user can find at least one way to use this product effectively. 2b. This product can be used with either the right or left hand alone. 2c. This product facilitates (or does not require) user accuracy and precision. 2d. This product can be used at whatever pace (quickly or slowly) the user prefers.
UDP3 Simple and Intuitive Use	3a. This product is as simple and straightforward as it can be. 3b. An untrained person could use this product without instructions. 3c. Any potential user can understand the language used in this product. 3d. The most important features of this product are the most obvious. 3e. This product provides feedback to the user.
UDP4 Perceptible Information	4a. This product can be used without hearing. 4b. This product can be used without sight. 4c. The features of this product can be clearly described in words (e.g., in instruction manuals or on telephone helplines). 4d. This product can be used by persons who use assistive devices (e.g., eyeglasses, hearing aids, sign language, or service animals).
UDP5 Tolerance for Error	5a. Product features are arranged according to their importance. 5b. This product draws the user's attention to errors or hazards. 5c. If the user makes a mistake with this product, it won't cause damage or injure the user. 5d. This product prompts the user to pay attention during critical tasks.
UDP6 Low Physical Effort	6a. This product can be used comfortably (e.g., without awkward movements or postures). 6b. This product can be used by someone who is weak or tired. 6c. This product can be used without repeating any motion enough to cause fatigue or pain. 6d. This product can be used without having to rest afterward.
UDP7 Size and Space for Approach and Use	7a. It is easy for a person of any size to see all the important elements of this product from any position (e.g., standing or seated). 7b. It is easy for a person of any size to reach all the important elements of this product from any position (e.g., standing or seated). 7c. This product can be used by a person with hands of any size. 7d. There is enough space to use this product with devices or assistance (e.g., wheelchair, oxygen tank, or service animal).

In spite of the UDP guidelines are prepared to improve the design, the real application in design practice merely only a formulation and a matter of opinion among designers [1][8]. The claim is backed by a statement from Mustaquim (2015) [9]that claims existing theoretical guidelines fail to contribute to the real application of universal design. There are no standard ways to evaluate UDP in terms of product performance that meet customer needs [9], [3].

Therefore, there is a need for integrating UDP with other methods to develop a systematic approach in order to improve a design involving disable people [8]. Integration with another tools is needed to identify the needs of UDP-related users to provide the best solution.

3. Theory of Inventive Principles (TRIZ)

To explore the potential of using TRIZ in the UDP approach, the previous study related to the integration of TRIZ reviewed. 4 integration of TRIZ is highlighted in this chapter.

3.1. Integration 1

A study by Pelt (2011) stated TRIZ has been widely applied to consumer product development, which needs to provide conclusive solutions and technical problems of customer needs [10]. This paper proposed an integration between TRIZ and human-centered design (HCD) using "Use", "Usability", and "Meaning" framework.

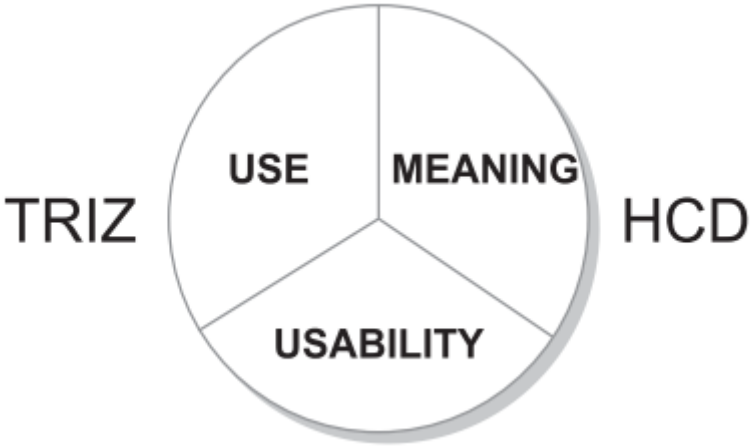

Figure 1. Diagram illustrating the different emphases of TRIZ and HCD [10].

Nevertheless, this study only discusses the potential of application of TRIZ within "Use", "Usability" and "Meaning" elements. This study concludes that from the potential of the application using TRIZ with "Use", "Usability" and "Meaning", there is an opportunity to adapt specific tools to understand consumer needs as TRIZ does not provide tools to understand consumers. This paper highlights the efforts made by Mann (2006) [17], Runhua (2002) [18], and Hipple (2006) [19] to understand the needs of the consumer in TRIZ.

Exploring previous research on TRIZ and UDP integration, similar literature of integrating TRIZ approach in universal design is reviewed.

3.2. Integration 2

A study conducted by C. M. Yang et al., (2010) [11] proposed a TRIZ-based innovative product design process that incorporates UDP. This study shows the importance of UDP through the whole product development process. However, this study only proposed an approach to evaluate the performance of each UDP using the Product Performance Program (PPP) in order to formulate the problems using the 3-step inventive problem-solving procedure in order to use the TRIZ contradiction matrix.

3.3. Integration 3

Jou (2013) [12] in his study attempted to integrate TRIZ with Taguchi's method in order to optimize process parameters of surface mount technology (SMT) assembly for core circuit board parts. It aims to optimize solder paste thickness during the solder paste printing process. This study integrates TRIZ and

Taguchi's method by revising the TRIZ contradiction matrix. The 39 parameters of TRIZ in worsening features is replaced with 13 parameters influencing the unevenness of solder paste. From the outcome of this study, he suggested that the integration of TRIZ and Taguchi's method is possible. The improvement in the single-to-noise ratio after the improvement using in confirmation experiment affects the lower rate of the defect.

3.4. Integration 4

Another sample of study TRIZ integration with the established method is reviewed. A study by Liu (2001) [13] developed a green innovation design method based on TRIZ innovative design methods. This study developed a table of the relationship between TRIZ 39 parameters and eco-efficiency elements. Each eco-efficiency element's properties are reflected in TRIZ 39 parameters. The main idea of this study is to translate the eco-efficiency problem to the TRIZ problem. As an example, "material intensity" is reflected in the closely related engineering parameter of TRIZ, such as weight, dimensions, shape and the number of materials used. A potential solution is proposed referring to TRIZ 40 inventive principles. However, the relationship between eco-efficiency and TRIZ 39 parameters established by this study did not involve any TRIZ experts.

4. Methodology

The main objective of this study is to focus on the integration between TRIZ and UDP to understand the design needs required by the consumer. In order to achieve this objective, this paper will simplify the process proposed by Yang et al., (2010) [11] to construct the UDP and TRIZ 40 inventive principles relationship systematically.

To establish the relationship between UDP and TRIZ 40 inventive principles, the participation of certified TRIZ experts is needed. Group of 6 certified Malaysian TRIZ experts examined all UDP and try to establish a relationship with TRIZ 40 inventive principles. TRIZ 40 inventive principles is listed in Table 3. Each UDP is considered as an improving parameter, and each TRIZ 40 inventive principles is examined to fit the UDP. In order to establish the relationship, the problem of each UDP guideline is transferred to the TRIZ problem.

Table 3. TRIZ 40 Inventive Principles [14].

1. Segmentation	9. Preliminary Anti-action	17. Another Dimensions	25. Self-service	33. Homogeneity
2. Taking Out or extraction	10. Preliminary Action	18. Mechanical Vibrations	26. Copying	34. Discarding and recovering
3. Local Quality	11. Beforehand cushioning	19. Periodic Action	27. Cheap short-living objects	35. Parameter Changes
4. Asymmetry	12. Equipotentiality	20. Continuity of Useful Action	28. Mechanics substitution	36. Phase Transitions
5. Merging	13. The other way round	21. Skipping	29. Pneumatics and Hydraulics	37. Thermal Expansion
6. Universality	14. Spheroidality - Curvature	22. Blessing in Disguise	30. Flexible Shells and Thin Films	38. Strong Oxidants
7. Nested Doll	15. Dynamics	23. Feedback	31. Porous Materials	39. Inert Atmosphere
8. Anti-Weight	16. Partial or Excessive Actions	24. Intermediary	32. Colour Changers	40. Composite Materials

The relationship between UDP and TRIZ 40 inventive principles is mapped using a table adapted from the study of Yang et al., (2010) [11], as shown in Table 4. After establishing this relationship, feedback from all TRIZ experts is gathered in a focus group discussion. The objective of this focus group discussion is to collect feedback from the TRIZ experts on the overall process mapping the suitability of 40 TRIZ 40 inventive principles with UDP. Comments from TRIZ experts will take into consideration to develop a more robust integration model of UDP and TRIZ.

Table 4. UDP – TRIZ 40 Inventive Principles Mapping Tables.

Principle	Guideline	TRIZ 40 inventive principles
UDP1 Equitable Use	1a. All potential users could use this product in essentially the same way, regardless of differences in their abilities.	
	1b. Potential users could use this product without feeling segregated or stigmatized because of differences in personal capabilities.	
	1c. Potential users of this product have access to all features of privacy, security,	

	and safety, regardless of personal capabilities.
	1d. This product appeals to all potential users.
UDP2 Flexibility in Use	2a. Every potential user can find at least one way to use this product effectively.
	2b. This product can be used with either the right or left hand alone.
	2c. This product facilitates (or does not require) user accuracy and precision.
	2d. This product can be used at whatever pace (quickly or slowly) the user prefers.
UDP3 Simple and Intuitive Use	3a. This product is as simple and straightforward as it can be.
	3b. An untrained person could use this product without instructions.
	3c. Any potential user can understand the language used in this product.
	3d. The most important features of this product are the most obvious.
	3e. This product provides feedback to the user.
UDP4 Perceptible Information	4a. This product can be used without hearing.
	4b. This product can be used without sight.
	4c. The features of this product can be clearly described in words (e.g., in instruction manuals or on telephone help lines).
	4d. This product can be used by persons who use assistive devices (e.g., eyeglasses, hearing aids, sign language, or service animals).
UDP5 Tolerance for Error	5a. Product features are arranged according to their importance.
	5b. This product draws the user's attention to errors or hazards.
	5c. If the user makes a mistake with this product, it won't cause damage or injure the user.
	5d. This product prompts the user to pay attention during critical tasks.
UDP6 Low Physical Effort	6a. This product can be used comfortably (e.g., without awkward movements or postures).
	6b. This product can be used by someone who is weak or tired.
	6c. This product can be used without repeating any motion enough to cause fatigue or pain.

	6d. This product can be used without having to rest afterward.
UDP7 Size and Space for Approach and Use	7a. It is easy for a person of any size to see all the important elements of this product from any position (e.g., standing or seated).
	7b. It is easy for a person of any size to reach all the important elements of this product from any position (e.g., standing or seated).
	7c. This product can be used by a person with hands of any size.
	7d. There is enough space to use this product with devices or assistance (e.g., wheelchair, oxygen tank, or service animal).

5. Results

To establish the relationship between UDP and TRIZ 40 inventive principles, the experts examine the definition of each UDP guideline carefully. Experts try to use synonym keywords in order to correlate UDP and TRIZ 40 inventive principles. Experts also use various examples to illustrate the definitions of each UDP for better understanding. This allows the experts to view the extent of the issues that the guidelines want to resolve. By the end of the session, all experts agree with the final relationship established. The result is shown in Table 5:

Table 5. Result of UDP – TRIZ 40 Inventive Principles Mapping Tables.

Principle	Guideline	TRIZ 40 inventive principles
UDP1 Equitable Use	1a	6, 26, 33, 40
	1b	6
	1c	6, 5, 11
	1d	6, 5, 30
UDP2 Flexibility in Use	2a	6, 4, 7
	2b	6, 13, 17
	2c	6, 4, 7
	2d	6, 7, 15
UDP3 Simple and Intuitive Use	3a	3, 6
	3b	25, 6
	3c	25, 6
	3d	3, 6
	3e	23, 32
UDP4 Perceptible Information	4a	6, 18, 19, 32
	4b	6, 18, 19, 32
	4c	6
	4d	6, 24, 26, 35, 36
UDP5 Tolerance for Error	5a	2
	5b	10, 16
	5c	2, 6, 9, 11, 22, 34
	5d	2, 9, 10, 23
UDP6	6a	6, 4, 12, 15, 24, 28, 29, 39

Low Physical Effort	6b	6, 4, 8
	6c	8, 12, 14, 20, 27
	6d	20
	7a	6, 1, 7
UDP7	7b	6, 37
Size and Space for Approach and Use	7c	6, 7
	7d	6, 24, 39

Three TRIZ 40 inventive principles was found uncertain to be correlate with any UDP guidelines. They are:

5.1. Skipping
This principle defines as a process using high speed. The process involves a destructible, harmful, or hazardous operation [14]. This process is not suitable for people with disabilities.

5.2. Porous Materials
This principle defines use of porous object in design [14]. There is no related UDP highlighting selection of materials. Thus this principle is uncertain with any UDP at the moment.

5.3. Strong Oxidants
This principle defines use of oxidizing agent in the process [14]. There is no related UDP highlighting usage of oxidizing agent. Thus this principle is uncertain with any UDP.

However, experts have agreed that all three of these principles are not yet fully removed from this relationship. It is possible for these three TRIZ 40 inventive principles can relate to UDP. Experts suggesting the usage of the TRIZ contradiction matrix is needed.

Figure 2. Discussion session with certified Malaysian TRIZ experts.

In the discussion, experts agree the potential of the integration will benefit on product design. It could improve the idea generation process of designers to become more focused and organized in designing for disabled people. According to the experts, both TRIZ and UDP methods are possible to cooperate. In practice, UDP is a guideline for a designer for consideration before generating ideas, whereas TRIZ can be used to identify, analyze and provide a solution to the problem. Besides, TRIZ is more towards analysis on existing product and problem solving; thus, TRIZ can be used for the future development of products incorporating UDP in the process.

TRIZ and UDP integration is something very new, and it is possible to be done. In another opinion, the experts stated UDP is more focused on the disabled people, while the TRIZ inventive is for a wide

range of users. Experts expect that the outcome of this UDP and TRIZ model can be a tool to shorten design time and reduce complexity in finding solutions.

In order to improve the integration, experts suggest an analogical or technical approach to establish a relationship between UDP and TRIZ 40 inventive principles. Another comment from the experts said that TRIZ solves a problem using generic keywords and principles. Therefore, keywords and synonyms between UDP and TRIZ are helpful in establishing the relationship. Lots of linguistic understanding is needed in order to establish a relationship.

However. the experts struggle to understand clearly the reference of UDP. This situation also stated in the study of Van der Linden (2016) [15]. Experts suggest including TRIZ 39 parameters to improve the model. The parameters can be translated in the form of products, that can help identify TRIZ 40 inventive principles much more accurate.

Experts also found the similarity in each UDP guideline with TRIZ 39 parameters. Each UDP guideline explains the parameter of the product. Thus, mapping with TRIZ 39 parameters is possible. Using TRIZ 39 parameters will significantly improve the suitability with UDP. In order to establish an integration model, experts suggest adaptation onto the existing TRIZ contradiction matrix incorporating the UDP as part of the contradiction parameters. The suggestion is similar to the previous study by Liu (2001) [13]. The TRIZ 39 parameters are listed in Table 6.

Table 6. TRIZ 39 Parameters [14].

1. Weight of moving object	9. Speed	17. Temperature	25. Loss of time	33. Ease of operation
2. Weight of stationary object	10. Force	18. Illumination intensity	26. Quantity of substance/the matter	34. Ease of repair
3. Length of moving object	11. Stress or pressure	19. Use of energy by moving object	27. Reliability	35. Adaptability or versatility
4. Length of stationary object	12. Shape	20. Use of energy by stationary object	28. Measurement accuracy	36. Device complexity
5. Area of moving object	13. Stability of the object's composition	21. Power	29. Manufacturing precision	37. Difficulty of detecting and measuring
6. Area of stationary object	14. Strength	22. Loss of energy	30. External harm affects the object	38. Extent of automation
7. Volume of moving object	15. Duration of action by a moving object	23. Loss of substance	31. Object-generated harmful factors	39. Productivity
8. Volume of stationary object	16. Duration of action by a stationary object	24. Loss of information	32. Ease of manufacture	

6. Conclusion

To improve the integration between UDP and TRIZ, an adaptation of the TRIZ contradiction matrix is needed. The incorporation of UDP with TRIZ 39 parameters is important. The TRIZ contradiction matrix for solving technical contradictions will be the base platform for the incorporation of the UDP-TRIZ model.

In the vertical description of Matrix is the TRIZ 39 parameters for a designer to improve. The horizontal description of Matrix shows the translated UDP guidelines associated with each UDP. The UDP-TRIZ contradiction matrix shown in Figure 3.

	UDP1				UDP2				UDP3					UDP4				UDP5				UDP6				UDP7			
	1a	1b	1c	1d	2a	2b	2c	2d	3a	3b	3c	3d	3e	4a	4b	4c	4d	5a	5b	5c	5d	6a	6b	6c	6d	7a	7b	7c	7d
1.																													
39 Engineering Parameters																													
39.																													

Figure 3. UDP – TRIZ Matrix

UDP guidelines should be translated into TRIZ 39 Parameters. This translation is similar to the previous study by Liu (2001) [13], where each UDP guideline to be examined and the relationship between UDP and TRIZ 39 parameters shall correlate. For example, UDP guideline 7a*, "It is easy for a person of any size to see all the important elements of this product from any position (e.g., standing or seated)"*, it can match with TRIZ 39 parameters number 12 *"shape"*. Thus, UDP 7a will be translated to TRIZ 39 parameters 12.

There is a possibility; single UDP guidelines translation may match with more than one TRIZ 39 parameters. Original TRIZ contradiction matrix for solving technical contradictions will use as a reference to map the TRIZ 40 inventive principles into the UDP-TRIZ model. The contradiction between improving parameters with associated worsening parameters will result in suggestions of up to four TRIZ 40 inventive principles. Therefore, the TRIZ 40 inventive principles propose in the matrix will be mapped to the UDP-TRIZ model. The conversion and finalization of UDP guidelines to TRIZ 39 parameters is still a work in progress.

7. References

[1] Heylighen V. Van der Linden and Van Steenwinkel I 2017 *Building and Environment* **114** 507–517
[2] K. C. Wu and L. Y. Song 2017 *Appl. Ergon.* **58** 254–264,
[3] Shahrin S, Rahman K, Kamarudin K and Che Me R 2019 *IOP Conference Series: Materials Science and Engineering* **551** 012109
[4] John Clarkson P and Coleman R 2015 *Applied ergonomics* **46** 235–247
[5] Waller S, Bradley M, Hosking I and Clarkson P J 2015 *Applied ergonomics* **46** 297–303
[6] Murphy J 2005 *The inmates are running the asylum [Book Reveiws]* **43** IN: Sams No 1
[7] Smith W F E P K H 2012 *Universal design handbook (2nd ed.)* **25**(3)
[8] Basnak M, Tauke B and Weidemann S 2015 *Architectural Research* 670–677
[9] Mustaquim M M 2015 *Procedia Computer Science* **67** 57–66
[10] Van Pelt and Hey J 2011 *Procedia Engineering* **9** 688–693
[11] Yang C M et al. 2010 *International Journal of Systematic Innovation* **1**(1) 49–60
[12] Jou Y T, Lin W T, Lee W C and Yeh T M 2013 *Advances in Materials Science and Engineering*
[13] Liu C Cand Chen J L 2001 *Proceedings Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing* 168–173
[14] Altshuller G 2002 *40 principles: TRIZ keys to innovation* **1** Technical Innovation Center, Inc.
[15] Van der Linden V, Dong H and Heylighen A 2016 *NA* **28**(2)
[16] Liu C C and Chen J L 2001 *The TRIZ Journal*
[17] Mann D L 2006 "Unleashing the Voice of the Product and the Voice of the Process" *TRIZCON Milwaukee*

[18] Runhua T 2002 "Voice of customers pushed by directed evolution" *TRIZ Journal*
[19] Hipple J 2006 "The use of TRIZ principles in consumer product design" *Proceedings of the TRIZ Conference*

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