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DESIGNING COMPUTATION AND IMPROVEMENT MODEL FOR RELIABILITY USING TOPSIS TECHNIQUE

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ABSTRACT
Reliability is the integral part of planning, designing and operating in engineering systems from the simplest and smallest systems to the most sophisticated and the biggest ones. When a system stops working, it makes personnel and related equipment working hampered and this problem can be considered as serious threat for people. Therefore, in this study at first we tried to identify existing models for reliability calculation in all phases of the product life cycle, then causal relationship between techniques in each phases is determined and for the first time in a systematic manner in order to improve equipment reliability to understand and develop the relationship between equipment, reliability was obtained, also regarding to its simplicity and applicability in most systems, it is used for equipment reliability optimization. The Product development levels regarding to the technical and qualitative techniques needed to achieve the desired reliability, are defined in eight-phase in the model.

KEY WORDS: Product life cycle, Reliability assignment, Reliability model, TOPSIS.

INTRODUCTION

Today, more than ever, designers and producers are interested in assuring reliable and correct function in industrial productions. They pay especial attention to improving reliability in order to assure buyers that they spend their money on durable products and they are safe from dangers during working with them. Hence, reliability is considered as one of important factors in function evaluation and failure rate prediction in systems, theoretically it defined as "the probability of performing a given operation by that component under stated conditions for a specified period of time." Reliability is usually used to express a degree of reliable function of a component or system under stated conditions for a specified period successfully. However, it does not mean if a part or system stops working, it is certainly unreliable. If there is a series of abilities including reliability, maintainability, accessibility, safety, durability and usability for a system, we say that the system is have reliability. It is necessary to have accurate plan and design in order to document tasks, methods, instruments, analyses and tests needed by a given system and achieve desirable level of reliability. Therefore, having a proper plan is needed from the beginning of designing and developing system to achieve favorable reliability. This plan not only defines the duties of reliability engineers, but also includes other’s duties in an organization. As a result, in this study, using the required techniques and procedures in each of the product life cycles are examined, and needed resolution for optimum and efficient use to achieve reliability targets are considered.

Existing models in reliability computation and improvement

Today, because of the importance of high quality and reliability, extensive research has been conducted in this regard. For example, Onoufriou evaluated the reliability of fixed steel offshore platforms under environment heavy load (Onoufriou and Forbes, 2001). and Avontuur investigates reliability role in the conceptual design phase of drive trains and proposes a new method for analyzing reliability in mechanical and hydraulic systems (Avontuur and van der Werff, 2001 and 2002). Zou investigates reliability in car's door and considers the amount of consumed energy for closing door as an important qualitative parameter (Zou *et al*., 2002). Lin investigates reliability in a random flow network with the probability of failures at nodes and arcs. Dutuit estimates reliability in a system with independent repairable parts, via fault trees analysis by binary decision matrix (Dutuit and Rauzy, 2005) from a different point of view, investigates reliability improvement in parts and systems using fault power reduction technique, Doguc proposes a possible model for using Bayesian networks in reliability estimation (Doguc and Ramirez-Marquez, 2009). Kiureghian deals with multi-scale reliability analysis and updating of complex systems by use of linear programming (Der Kiureghian and Song, 2008). Wilson calculates reliability using Bayesian method in two parallel and series systems under uncertainty condition (Wilson *et al*., 2011) and Bichon in that year analyzes system reliability of system with multiple failure modes using replacement Gaussian model (Bichon *et al*., 2011) and Aubert calculates reliability for insulated TRIAC polar lamp package life (Aubert *et al*., 2011), Li calculates Finite-element-based system reliability analysis of fatigue-induced sequential failures using bound and branch method (Lee and Song, 2012), Castellazzi investigates reliability improvement in electricity generating system using dynamic active cooling (Castellazzi *et al*., 2011) and dong predicts reliability and fatigue in welds of pipe joints in supporting structure of fixed jacket of marine wind turbine at the depth of 70 meters (Dong *et al*., 2012) and Frémont proposes a model in order to predict reliability in microelectronics series (Frémont *et al*., 2015).As it clear, Different aspects of reliability process are considered in mentioned researches and In general, none of mentioned research considers product formation process for achieving desirable reliability in systems and sub-systems. Hence, we tried to sort the techniques in eight phases of product life cycle just like the conceptual model in diagram (1).

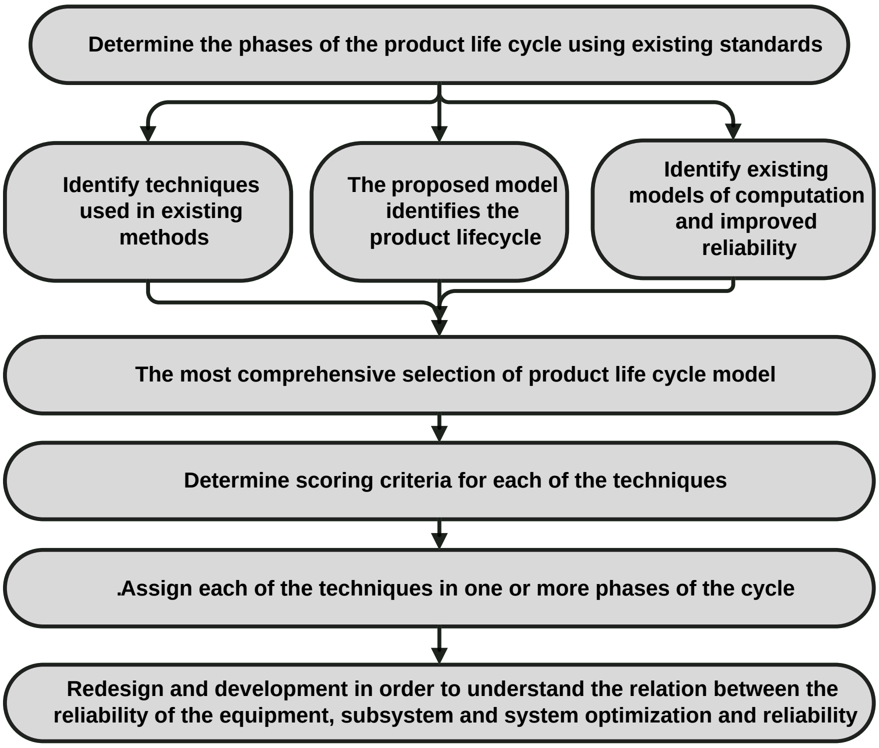

Diagram (1): conceptual model of research

Existing models in reliability computation and improvement

NASA company model

As it has been shown in diagram (2), this model has shown the monitoring and evaluation of the processes of management in order as a general scheme by NASA Company and it has been considered theoretically, also mentioned this point that more details should be investigated in fact. This General scheme deals with the detection of faults causes by tests, as well as the reliability assignment and planning has been discussed.

Li model:

Lee and Song (2012) showed eight initial phases in order to achieve reliability as shown in diagram (3). This diagram shows eight initial phases in designing effective reliability. These phases include mission define definition, design guidelines, analysis design, parts reliability, periodic reviews design, manufacturing, assessment testing and operational testing. In first phase, product mission is defined and in second phase, necessary reliability and costs are considered. In third phase, design engineers propose additional designs instructions such as necessary load criteria, design margins and necessary standards of parts. In design analysis, in third phase, thermal stress, electrical cases, tolerances and scheduling are investigated and fault and failure probabilities are analyzed in order to predict maintainability and reliability for system.

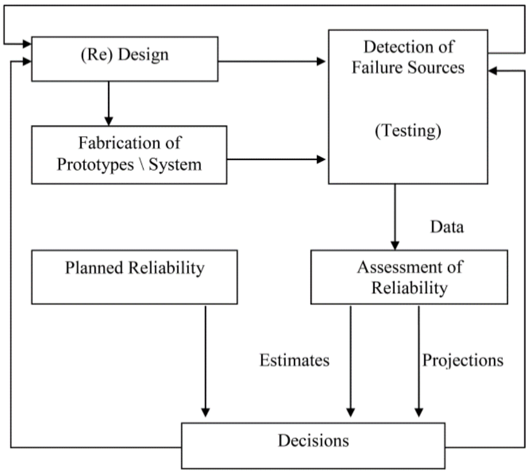

Diagram (2): the reliable growth management model MIL-HDBK-189C

This prediction is conducted in order to compare existing system with the ideal one. In the next phase, parts reliability is extensively investigated. In this phase, suppliers and reliability requirements are considered and non-standard parts that can't provide the desired capability are identified and modified. In fifth phase, design is investigated periodically. In sixth phase, operational tests and normal growth are conducted by a series of tests to estimate and compare real system with ideal one. In seventh phase, tests are evaluated and in the last phases, the development of process productivity and training programs for product are considered.

Fayssall model

Fayssall *et al* (1996) employees of spatial company of NASA, showed reliability in the phases of product design as shown in diagram (4). This model divides reliability into reliability design and reliability process. In reliability design, tension and strength are considered as two dependent variables. Tension variable is considered as a function of environment, loads and operational condition. Process critical parameters, processing method and process control are considered in process discussion.

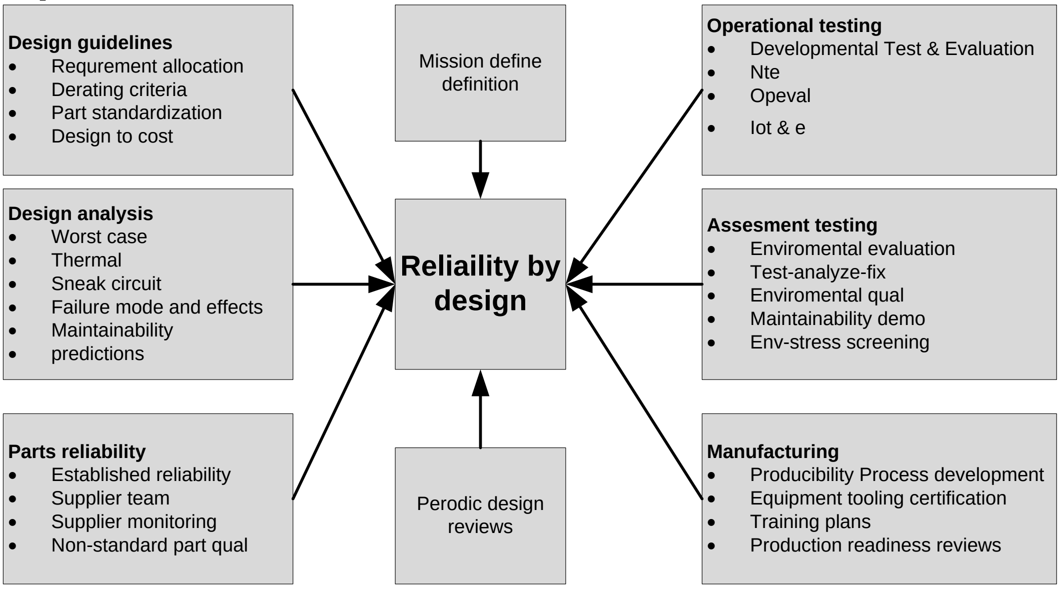

Diagram (4): Lee and Song (2012) model in 1991

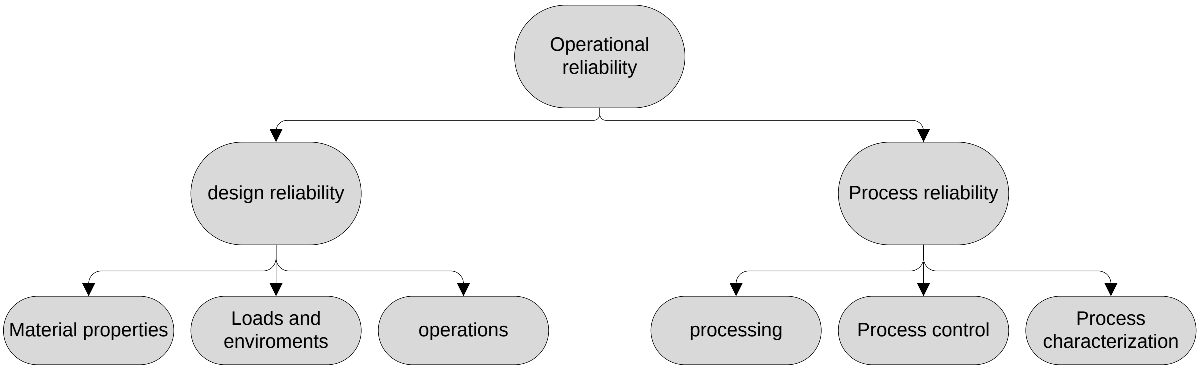

Diagram (4): fayssal et al model in 1996

Levin model

Levin (2003) divided reliability process into some phases including conceptual design, production and product life end in their book as shown in diagram (5). In conceptual design phase, product concept is defined based on business and market requirements and then functions and design adequacy are confirmed in design phase. In production phase, design is transformed into product and necessary optimization is conducted and finally, worn-out parts and materials are removed from warehouse inventory and new products are replaced after the useful life end of old product.

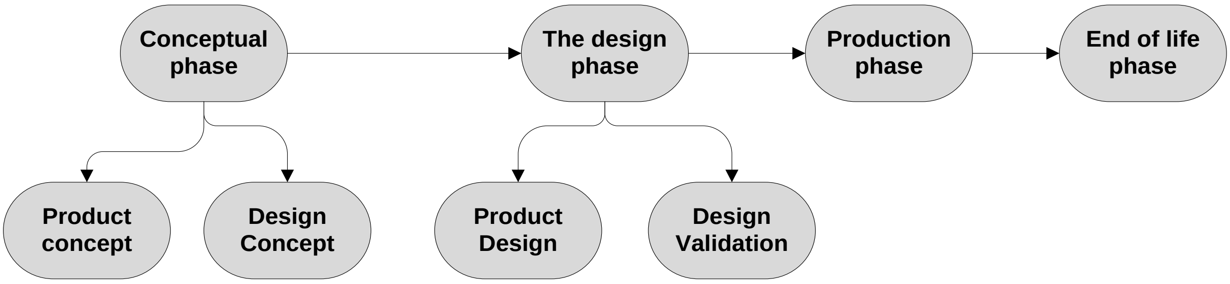

Diagram (5): Levin (2003)

A comparison of four models are shown in Tables (1) and (2):

Table(1) :A comparison of four models studied

model	Researcher	year	Subject and application	How to provide model
Model 1	NASA	2011	MIL-HDBK-189C	**Generally provided**
Model 2	Lee et al.	1991	Construction of shuttle	**The eight phases are considered in more detail**
Model 3	Faysal	1996	Military equipment	**Two-phase process and design are provided**
Model 4	levin	2003	Aerospace industry	**The four phases of the product life cycle model presented by considering the details.**

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Table (2) :A comparison of four models studied

model	design	Fabrication of	Assessment of	Design guidelines	Parts reliability	Periodic design reviews	Operational testing	Assessment testing	Manufacturing	Process reliability
Model 1	•	•	•							
Model 2	•			•	•	•	•	•	•	
Model 3	•									•
Model 4	•	•					•		•	•

Determination of product life cycle phases using existing standards

Product life cycle covers all necessary activities from designing product and procurement raw materials to delivering finished product and offering post-sale service. These activities include research and development (R&D), product designing, manufacturing, sale, marketing, advertising and post-sale service. Following points were investigated in order to determine necessary phases for the completion of product life cycle:

- Product life cycle covers all necessary activities from designing product and procurement raw materials to delivering finished product and offering post-sale service. These activities include research and development, designing product, manufacturing, sales, marketing, advertising and post-sale service. Diagram (5) shows the product life cycle system proposed by Fabriki and Blanchard.

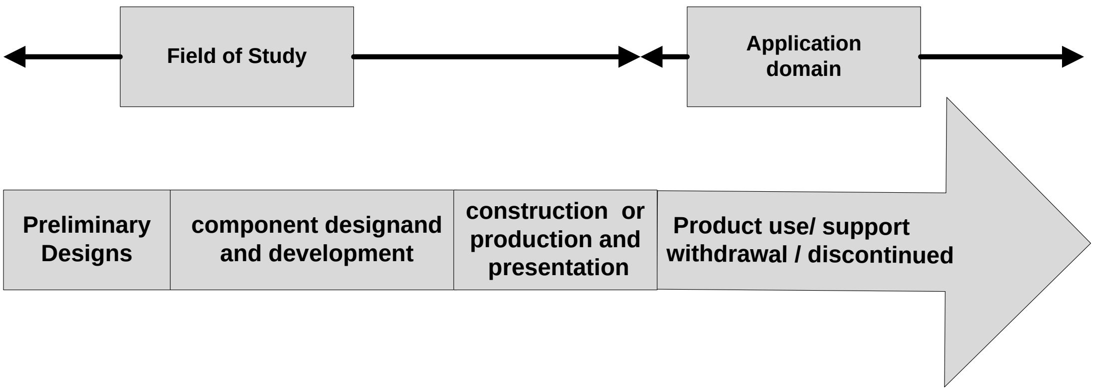

Diagram (5): Fabriki and Blanchard model 1991

- According to diagram (6), ASAS-ST-RF121:1391 standard shows product life cycle in the organization of aero-space industries.

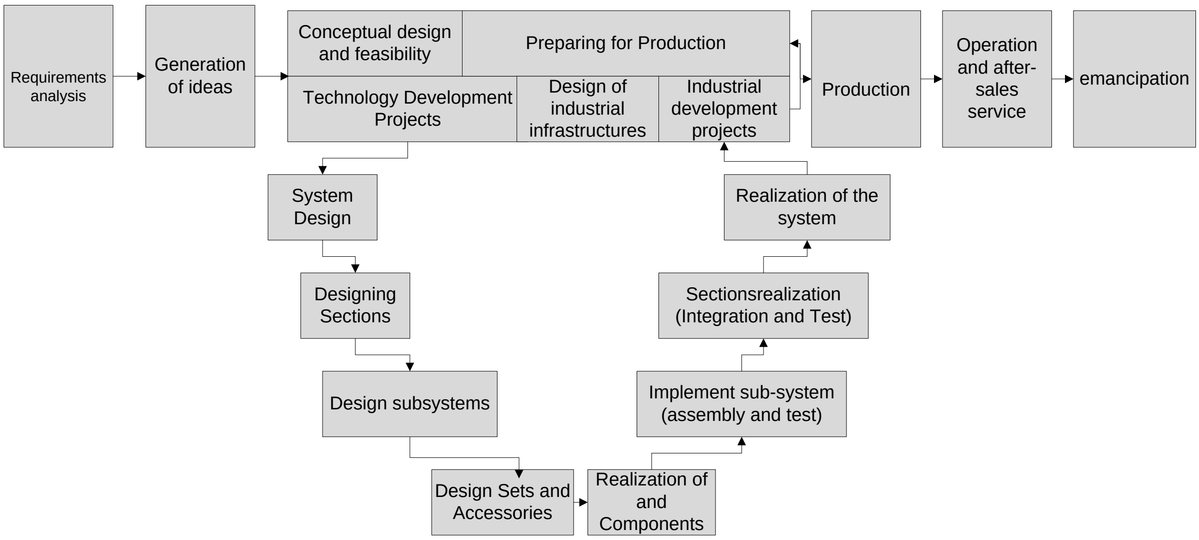

Diagram (6): technical review in product life cycle

- NASA Company proposed eight phases in 7120 standard as follows below and according to the completeness of the model relative to other models, it was considered as a desirable model in this research. Eight phases include:

1. Requirement analysis
2. Feasibility and conceptual design
3. Preliminary design
4. Final design
5. Manufacturing Prototype and engineering development
6. Product design and development
7. Process design and development
8. Supporting operations application and confirmation

Identifying necessary techniques for reliability calculation and improvement in all phase of product life cycle

There are many instruments and methods with their own advantages for design engineers that are applicable for different phases of designing and product manufacturing. Hence, in this research, we have tried to identify effective techniques on product life cycle and classify them in each phase so that they can be used optimally.
A series of techniques were selected from industry engineering handbook and resources including 68 defining techniques, with the assistance of experts in the design and engineering departments of armaments industries in Isfahan province. These techniques are shown in table (3).

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1	FFBD	35	Reliability Allocation (foo Method)
2	Check there is no contradiction in the following sections and systems reliability	36	Determine objectives and requirements for product reliability
3	complete Production planning and detailed design	37	Define the steps that must be performed by subcontractors
4	To ensure the reliability of the system and the resulting systems HALT, HASS	38	Benchmarking conducted on the reliability of similar products
5	complete documentation for of systems design and test	39	Mission Requirements Analysis
6	Preparing for manufacturing	40	Revised schedule
7	Assess the ability of providing the infrastructure and	41	Packaging design
8	assessment , verification and validation of design	42	FTA
9	Calculation of Reliability	43	Analysis and Assessment Product Specifications
10	Requirements analysis and correction	44	Matrix of relationships between key features and characteristics of the product
11	DFMEA	45	tolerance design
12	Revision of quality system processes and products	46	Allocation of reliability with minimal effort
13	Assembly and integration of the physical of systems	47	FMEA
14	QFD (four level)	48	Evaluate the economic feasibility of reliably
15	complete drawings / documents for final items	49	Check the status of identified risks in DFMEA
16	Operation process chart	50	Updating tools list
17	Identification of nonconformities and review of systems and sub-systems using fault tree analysis	51	Support Systems Analysis
18	Presentation and production process prototype OPC, FPC and APC	52	Tests specified nonconformities in of systems validation and verification by product
19	Assessment and analysis of systems concepts and final items	53	Development of assessment standards
20	Product testing	54	Design factory layout
21	assessment Quality records Similar Products	55	assessment, verification and validation of design
22	Readiness of construction	56	Display performance operational capabilities
23	Product technical specifications sheet	57	Set of assumptions and limitations of the product
24	Manpower development and training of employees on reliability	58	Allocation requirements
25	Parameter design	59	The process capability study before series production
26	Developing Control Plan	60	Systems design and documentation updates
27	Developing MSA	61	The relationship between product features and customer comments (House of Quality)
28	RISK ANALISYSES	62	simulation in order to evaluate Technical tests before the sample
29	Identify suppliers	63	Updating PFMEA
30	CAUSE AND EFFECT DIAGRAM	64	control of nonconformities
31	Developing TEST PLAN	65	storing and monitoring data and compared with the desired reliability
32	Review of operations	66	Providing equipment and tools and gauge control
33	Staff training	67	Maintenance service Analysis
34	DOE	68	Voice of customer on reliability : VOC

Determination of scoring criteria for each method

Selecting a technique needs detailed analysis. Selected technique should be consistent with strategic aims of the organization. Pand *et al* (2000) divided criteria related to selecting project into three classes:

1. Project advantages for business
2. Project accessibility
3. Project effect on organization

Project advantages for business cover discussions such as effect on customers, effect on business strategy, effect on central qualities and immediate financial effects. Accessibility criteria for selecting 6-sigma project cover such criteria as required resources, available expertise, complexity and success probability, learning and cross tasks. These criteria are considered as organizational effects technique. Suggested following criteria for selecting project (Harry, 1998).

1. Net amount of saving in costs
2. Cycle time
3. Customer satisfaction
4. Internal function

Balanos *et al* (2006) suggested following criteria as six vital criteria for selecting techniques (Banuelas *et al*., 2006).

1. Effect on customer
2. Financial effects
3. Top management obligation
4. Measurability and availability
5. Growth and learning
6. Connection to business strategy and main adequacy

Assigning each technique to each phase needed scoring and determining priorities. Therefore, a meeting was held and all industry experts participated in it. At first, all criteria were determined by brainstorming method. These criteria could be used to rank techniques. After that, these criteria were classified in priority using pairing comparisons technique and four criteria were selected as the most important criteria in using techniques in each phase. The weight of each criterion was determined using AHP method as shown in table (4).

Determined criteria include:

1. Cost of technique performance
2. Required time of technique performance
3. Application extent in each standard phase
4. Simplicity of technique performance

Table (4): Measures weight defined by AHP

Criteria	Simplicity of technique performance	Application extent in each standard phase	Required time of technique performance	Cost of technique performance
weight	0.1	0.5	0.2	**0.2**

Assigning each technique to one phase or more in cycle

Similarity to idea case technique, as one of multi-criteria decision techniques, was used to assign each technique to determined phases and the ideas of all related experts were collected using eight forms in each phase based on mentioned criteria. After collecting ideas, results were analyzed by excel software (appendix 1) and each technique was assigned to determined phases as shown in tables (5) and (6).

Table (5): Technique's Score

Requirements analysis		Conceptual design		Preliminary design		The final design		Manufacturing Prototype	
Score	Technique	**Score**	Technique	**Score**	Technique	**Score**	Technique	**Score**	**Technique**
0.6127	36	0.59897	43	0.580648	19	0.591857	8	0.604356	**20**
0.5835	24	0.579757	39	0.589759	10	0.633877	64	0.589759	**4**
0.6010	68	0.58216	53	0.589759	55	0.617586	22	0.580796	**52**
0.5777	38	0.593222	7	0.588125	17	0.592135	18		
0.5956	57	0.586884	48	0.579048	49	0.595059	1		
		0.595688	61	0.589759	2	0.580697	42		
		0.614846	35			0.593089	47		
		0.580312	11			0.605933	30		
		0.658182	28			0.567896	34		
		0.605933	58			0.567896	14		
						0.594131	25		
						0.617586	45		
						0.598052	46		
						0.578835	3		
						0.591857	6		

Table (6): Technique's Score

Product design and development		Process design and development		Implementation and verification	
Score	Technique	**Score**	Technique	**Score**	**Technique**
0.580312	13	0.623941	40	0.543224	**56**
0.604184	5	0.577896	12	0.574527	**33**
0.591317	21	0.562495	37	0.542408	**51**
0.605756	23	0.564372	29	0.544724	**67**
0.558644	16	0.562364	44	0.530519	**60**
0.589759	41	0.57099	26	0.532606	**9**
0.575972	54	0.567378	27	0.530519	**65**
		0.567378	50		
		0.567875	59		
		0.610496	31		
		0.567812	63		
		0.567378	66		
		0.557348	62		
		0.556183	32		

CONCLUSION AND SUGGESTIONS

In this research, after identifying existing cycles in the area of product life, all techniques related to reliability improvement were determined. Then, used models in the area of reliability improvement were investigated. Therefore, after selecting more complete life cycle and similarity to ideal case technique, one of multi-criteria decision techniques, all identified techniques were classified between product life phases and for first time, a systematic model was obtained in the direction of reliability improvement of the equipment in order to understand and develop relationship between equipment reliabilities. A more comprehensive model should be used in future research compared with existing model and necessary human resources, time and financial resources related to it should be considered. Therefore, integrated models with project management can be used. Existing techniques in project management help reliability improvement in systems and subsystems and it is possible to achieve main purpose, these techniques implementation, in industry practically.

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