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The Effect of a Program Based on TRIZ Theory to Develop the Creative Thinking Skills Among Male Students with Mild Intellectual Disability

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Abstract

This research aims to identify the effectiveness of a (TRIZ) program on developing creative thinking skills among male students with mild intellectual disability. The research sample consisted of (7) male students with mild intellectual disability. Their age ranged between (11 and 13) years old, and they attend the school of intellectual education male in Kuwait. The research tools consisted of the Torrance test of creative thinking figural form B and the training program on developing creative thinking skills. One group quasi-experimental method was used in the research. The research results showed that there are statistically significant differences between the mean scores of the pre-test and post-test for the experimental group, in favour of the post-test. The research results also showed that there are statistically significant differences between the mean scores of the post-test THG8KUYK8JRF FOKM9I PRV MKFV [=R094IERKDFV and the follow-up test for the experimental group, in favour of the follow-up test, which demonstrates the effectiveness of a (TRIZ) program on developing creative thinking skills among male students with mild intellectual disability and maintained the skills students obtained from the program. The research recommended the preparation of special educational programs to train the students with an intellectual disability how to solve problems creatively and develop creative thinking skills and Providing a stimulating and encouraging environment through various activities and educational situations that
develop the creative abilities and skills of students with intellectual disabilities and enhance their self-confidence.and to training teachers and educational specialists on the TRIZ program and how to integrate program strategies with the educational curriculum and design other educational programs based on how to solve problems in creative ways. Also Encouraging researchers in the field of people with intellectual disabilities to design and develop similar programs to develop creative thinking skills within the curricula provided for these students or other independent programs.

Keywords: creative thinking, TRIZ program, intellectual disability

1.Introduction

The individuals with intellectual disability are considered as national energy and productive human wealth, in case of the means of care and attention that develop their abilities are provided and undertaking to provide ongoing care through a long-term vision, with following-up that focused on the individual through extended planning for several years to address all aspects of his life, capabilities, special abilities and preparations. In addition, to undertake the developing training programs & curricula for his care, development during his growing stages develop and follow it according to an organized scheme. Where it becomes a lifestyle that is interacted with and dealing based on (day-to-day) daily behavior and preparing

the individual for a promising future. This is the essence of the educational process for individuals with intellectual disability (Wells & Sheehey, 2012).

The role of educational institutions at all different academic levels lies in preparing, encouraging, and creating the appropriate environment to motivate student's creativity in various fields, adopting exploratory methods rather than the explanation and interpretation, focusing on understanding and application instead of memorizing, and benefiting from the accumulated experiences and expertise all over the world. According to a constructive-critical perspective, the formation of the creative personality of all categories of students, the development of their creative abilities towards useful and valuable things, and the develop their feelings towards working for the welfare and happiness of humanity (Habash, 2005).

In this time of acceleration, it is important to research and investigate all that is new in the educational fields and to benefit from it. And to employ theories in the field of special education that help us in developing teaching skills, thinking skills, and developing the field of research for people with intellectual disability in the future. When individuals with mild intellectual disability are taught and trained to acquire and develop creative thinking skills, they will be able to overcome the problems they face in their lives.

A student with a mild intellectual disability possesses latent creative talents and abilities regardless of the deficiencies in his physical, sensory, or mental abilities, as he can move towards society and others, where he begins to discover himself and his abilities and work to develop them, to come out in a creative form in which he competes with others. From members of the community, and thus his disability constituted a strong motive for him to prove himself in front of others (Abdat, 2013).

Creative thinking is one of the most important elements of thinking and its skills. Teachers must aspire to develop it among learners by developing their abilities to create ideas, training them to participate in developing knowledge and information of originality, fluency, flexibility and clarification, enabling them to solve their problems themselves after getting to know them and identifying their nature. And the search for solutions to them, then choosing the most appropriate solution to make the appropriate decision about them, which develop the-thought-out and well-executed educational program, by integrating creative thinking skills with the topics of the lessons, to achieve the required development for such skills for learners throughout the stages of their studies, and this works on developing creative thinking skills and raising their level of understanding of the issues and the issues they face in their daily lives (Al-Hallaq, 2010).

Special education is a fruitful field, in which workers can benefit from theories that have been tested in other fields, such as psychology, and use those theories to develop the capabilities, abilities and skills of children and adults with intellectual disability (Al-Mawla, 2013). Therefore, there is a need for programs with a clear methodology used to solve problems in creative methods, and based on a giant knowledge base of strategies that develop creative thinking skills, and the most famous and important of these programs is the (TRIZ) program, which began in the Soviet Union and was known as the solution theory " Theory of Inventive Problem Solving Also known as "TRIZ", the word is taken from the Russian acronym "Theory Resheniya Izobretatelskikh Zadatch", a relatively recent theory of creativity. Where the strength of this theory stems from its reliance on the various systems in the engi-

neering and technical fields that have been developed effectively and successfully, in addition to its ability to get rid of psychological obstacles that limit the interest of each group of people in their field of work only. This theory collected successful strategies and solutions from all fields of human activity and formulated them in the form of a set of tools that can be employed in various of these fields (Abu Jadu, 2012a).

TRIZ theory of innovative solutions to problems included a group of (40) strategies that can be used to find some unusual solutions to educational problems. As these principles showed their effectiveness in solving many engineering, technological and scientific problems, and also led to the emergence of a large number of inventions in these areas, and it is assumed that the application of such strategies in the field of education and upbringing of children with intellectual disability may help to solve their problems inappropriate ways and lead to the acquisition of developing and improve many of their abilities, skills and strengths, knowing that some of these strategies can be used with students with intellectual disability, while others are not appropriate for them (Al-Mawla, 2016).

Many research and educational studies in the field of intellectual disability have confirmed the existence of creative skills among the mentally disabled to a small degree, (Ismaeel, 2006; Al-Bashbeshi, 2008; Hassan, 2018), and a study (Cote et al, 2010; Fard et al, 2014; Gagic). et al, 2014; (De caroli & Sagone, 2014); (Petrulioniene & Valantinaite, 2015); Karabulute & Ozmen, 2018; Lant, 2019), And the distinctive characteristics that they possess if they are given care and attention and provide training programs and curricula to discover the creative skills and special abilities that exist in this category. Most of the studies focused on studying the differences between the individual with intellectual disability and normal children in creative thinking skills or revealing creative thinking skills among individuals with intellectual disability, but a few of them focused on designing an educational program to develop creative thinking skills and know its impact on students with intellectual disability.

To create suitable opportunities for talented and creative students with intellectual disability in the future to develop their creative energies and abilities, and to contribute to the development of life in their community, they must be given the appropriate care and attention that helps them develop their energies, abilities and talents. This requires educational enrichment programs that contribute to considering their needs and developing their creative thinking skills and linked in the real-life and the daily experiences of students with intellectual disability (Al-Ataar, 2011). Creativity training in an organized manner helps to identify the main goals and objectives, provide multiple opportunities for students to develop their creative abilities and skills by raising awareness and enhancing the creative traits of each student and teaching creative thinking techniques to be able to enhance their independence and self-expression and acquire lifelong learning skills (Davis & Rimm & Siegle, 2011).

TRIZ Strategies, which consists of a set of tools, methodologies, and a knowledge base designed to bring creative ideas into strategies that help change students' thinking and interactions in the daily life, and may motivate students with intellectual disability to make distinguished contributions in the creative field of life and to change the way the conduct of business and the alteration of daily activities (Fulbright, 2011).

Therefore, in this current research, some strategies of the (TRIZ) program will

be integrated into the science curriculum for schools of intellectual education for students with mild intellectual disability, taking into account the concepts and skills that must be acquired, and the type of thinking skill required for them.

2.Research Problem

The process of creativity, with its distinct characteristics, is greatly affected by the surroundings and the environment in which the individual lives. It is affected by customs, traditions, values and beliefs, and everything related to the cultural heritage of the community. Societies differ in their structure, culture and beliefs from each other, and some societies encourage independence and self-reliance and the spirit of development and progress without any restrictions or reservations, while a type of society does not encourage independence, and tends to suppress human capabilities that seek progress and development with restricting them (Abu Jadu, 2012a). and this is with individuals with intellectual disability, where the focus is on the aspects of their shortcomings and weaknesses, and the lack of interest in the aspects of strength and creativity, and considering them as effective individuals in their societies, and that people with intellectual disability need to upgrade the provided services and the educational programs provided to them by societies to be active members of society, and they keep pace and adapt to changes, speed and development in the face of the problems they are experiencing. Creativity and its development are important pillars in the lives of individuals with intellectual disability.

It has become necessary for educational institutions that include students with mild intellectual disability to give the subject of teaching thinking skills and creative thinking great importance by adopting modern programs and strategies that encourage thinking, learning and self-work. as the programs and curricula provided to them do not encourage or stimulate motivation and creativity even the learner with an intellectual disability reaches the required level of education, can face the challenges of the future and interact positively with its changes and developments (AL-khamis, 2018).

Through the researcher's review of the database, he noticed that few studies focused on the field of creative thinking among students with mild intellectual disability and the absence of the application of (TRIZ) theory in enrichment and training programs to develop their creative thinking skills, but the studies that dealt with the development of creative thinking skills and the application of enrichment programs educational for the development of special abilities and creative thinking skills for the individual with intellectual disability in general. It recommended the need to pay attention to this field, and the field of intellectual disability needs to search for everything that is new and helps in developing creative thinking skills for students with intellectual disability and to change the strategies and curricula that are presented to them in a new image that strengthens and raise their motivation and creativity.

(TRIZ) theory is based primarily on innovation and not being restricted to a single pattern of thinking, so it is necessary to search for what is new and innovative to benefit students with intellectual disability, and to provide them with new knowledge, or to help them get rid of their shortcomings, implemented by simplifying These strategies, and appropriately presenting them, can benefit students with intellectual disability (Al-Mawla, 2013).

The current research seeks to employ some strategies of a program based on (TRIZ) theory, which is represented in the strategy (Segmentation, Combining /

Merging, Inversion) to develop creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure) For the students with mild intellectual disability.

Therefore, the study problem can be formulated in the following main question:

What is the effect of a program based on (TRIZ) theory on developing creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure), among students with mild intellectual disability in the State of Kuwait?

The following questions arise from this question:

1. Does the (TRIZ) program lead to the development of creative thinking skills among a sample of students with mild intellectual disability?
2. Does the (TRIZ) program continue to develop creative thinking skills for a sample of students with a mild intellectual disability after a while (two weeks)?

3.Research Aims

The current research aims to:

3.1 Verifying the effect of a program based on (TRIZ) theory on developing creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure) among students with mild intellectual disability.

3.2 To verify the continuing impact of the program in developing creative thinking skills for a sample of students with a mild intellectual disability after a while (two weeks).

4. Research Terms

4.1 Intellectual Disability:

Students with mild intellectual disability can be defined procedurally as they are students with a mild intellectual disability according to the diagnosis of the Developmental Medicine Unit in the State of Kuwait, and their IQ ranges between (52-68) on the Stanford Binet Scale, and (55-69) on the Stanford Binet test Wechsler for children and their chronological ages (11-13 years).

4.2 Creative Thinking:

Creative thinking can be defined procedurally as the degree that the student obtains from the study sample on the Torrance test of creative thinking, formal form (B).

4.3 (TRIZ) Program:

Simon Safransky considers (TRIZ) as a systematic, human-oriented, knowledge-based methodology that aims to solve problems creatively (Abu Jadu, 2012a).

It is procedurally defined as a set of educational activities and aids aimed at developing creative thinking skills for students with a mild intellectual disability based on some (TRIZ) strategies: (the turned/reversal strategy, the merging/linking strategy, and the division/segmentation strategy).

5. Research Category

This research was applied in the first semester of the academic year 2020-2021 AD in the State of Kuwait on a sample of (7) students in the sixth grade.

6. Research Methodology

The research relied on quasi-experimental research to study the research problem and answer the questions about the problem, it was selected because it was the appropriate method to observe the changes resulting from the introduction of the independent variable and to achieve the goal of research. An experimental group was used to design the single group with a prior, post and follow-up test, as shown in Table (1). to verify the effectiveness of a program based on (TRIZ) as an independent variable in developing creative thinking skills for students with mild intellectual disability as a dependent variable.

Table 1. Experimental design for research

Group	Pre-test	processing	Post-test	Follow-up test
group				
Experimental one-group design	Torrance Test of Creative Thinking Figure B	Enrichment program based on (TRIZ) theory	Torrance Test of Creative Thinking Figure B	Torrance Test of Creative Thinking Figure B

7. Research Variables

The research included two types of variables, as follows:

7.1 Independent Variable

A TRIZ-based enrichment program to develop creative thinking skills in students with mild intellectual disability.

7.2 Dependent variable

It is the degree of creative thinking skills of a student with mild intellectual disability represented in Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure, on the Torrance Test of Creative Thinking, Figure. (B).

8. Research Community

The target research community consists of all students with mild intellectual disability in the School of Intellectual Education for Boys in the State of Kuwait, (169 students), according to the statistics of the Intellectual Education Schools of the Ministry of Education for the academic year 2020/2021 AD.

9. Research Samples

The research sample consisted of (7) students in the sixth grade in the School of Intellectual Education for Boys, and they were selected intentionally from several classes in the school, and their ages ranged between (11-13 years). The sample was selected according to the following criteria: that the student has a mild intellectual disability, that the student's intelligence rate on the Wechsler Test of Children's Intelligence ranged between (55-69), and on the Stanford Binet test in the State of Kuwait between (52-68), the student's chronological age should range between (11-14) years, and the student should not have any other disabilities associated with the intellectual disability.

10. Research Tools

To achieve the objectives of the current research, two tools have been used to measure the impact of the program in developing creative thinking skills, and measures for obtaining and analyzing **information** in the prepared research. The tools used in the research are detailed as below:

10.1 Torrance Test of Creative Thinking Shape (B)

This test aims to measure the degree of creative thinking, and this test was prepared by Paul Torrance and published in (1966 AD), and it can be used for all age levels, as the age range of the test ranges from (6-60) years, and it can be used for all levels of research, from the kindergarten to the postgraduate studies. the test measures four abilities: fluency, flexibility, originality, and Elaboration. In (2008) the test correction was developed to address the different divergent thinking skills, namely, fluency, originality, Elaboration, Abstractness of Titles, and Resistance to Premature Closure. The Torrance Shape Test (B) consists of three activities: the first activity (Picture Construction), and the second activity (completing the lines):

The psychometric properties were extracted by referring to the Torrance Tests of Creative Thinking (2008) manual, so the stability coefficients of the creative abilities of the Torrance formal form were calculated as shown in Table 2. It is noted that the stability coefficients for creative abilities are high and statistically significant, the reliability coefficients ranged between (0.966-0.999).

The Torrance test, in its American form, has different truthful connotations, with Torrance referring to the availability of the truthful content of the test, and also in a study of Torrance and Gupta in (1964).

Using the test of teachers' estimates to demonstrate the complementary truthfulness of peripheral categories, the scale was found to have a high ability to distinguish between the upper and lower categories in the test dimensions. (Fluency, flexibility, originality), and in (1972) Torrance began studying his followers to complete a sample of students that reached (236) students over 12 years, and when their achievements were linked to Torrance's test results, they were reported to males. (0.59) and for females (0.49), also in the (1974) Kruble study, when a sample of students was traced for five years and the correlation between their achievements and their connections in the Torrance test was found to have reached. (0,514) with an indicative level (0,01) is evidence of the predictive honesty of the test.

Psychometric properties of the test on the Kuwaiti environment

(Al-Tabikh, 2015) verified the validity and reliability of the Torrance test to measure creative thinking on a sample of the Kuwaiti environment, where the sample consisted of (45) male and female students, including (22) male students, and (23) female students from the class. The reliability coefficient values among the correctors were very high, indicating that the Torrance test had very high stability following the development of its correction method in 2008 AD. The coefficients of the reliability coefficient value between the correctors ranged between (0.941-1,000).

10.2 TRIZ Theory-Based Enrichment Training Program to Develop Creative Thinking Skills

Caring for the educated student with intellectual disability requires him to acquire the knowledge and skills that form the necessary scientific background for him, which interact in himself and lead him to search for other information further and deeper, using his experiences and skills, interacting with his environment with all its variables, generating new knowledge, which appears in various forms. It expresses creativity, such as generating a large number of ideas, solving

problems, or creating new ideas (Al-Mutairi, 2017).

The goal of efforts to teach thinking to students with an intellectual disability is to improve their skills in creative thinking, and thus train their students to take responsibility for integrating thinking skills into their daily practices, not only in the usual classes at school but in the various aspects of their life activities (Nawfal and Seifan, 2011).

TRIZ theory of innovative solutions to problems included a group of (40) strategies that can be used to find some unusual solutions to educational problems. These principles have demonstrated their effectiveness in solving many engineering, technological and scientific problems and have also led to the emergence of a large number of inventions in these areas. It is assumed that the application of such strategies in the field of education and education of children with intellectual disability may help to solve their problems inappropriate ways and lead to the acquisition, development and improvement of their many abilities, skills and strengths (Al-Mawla, 2016).

11. Program Overall Objective

The overall objective of the program is to develop creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure) for students with a mild intellectual disability based on (TRIZ) strategies: (Segmentation, Combining / Merging, Inversion)

12. Nature of the Program

This program develops creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure), by integrating some of (TRIZ) strategies into the science curriculum for sixth grade in schools of intellectual education. The program includes the application of three TRIZ strategies (TRIZ) which is (Segmentation, Combining / Merging, Inversion).

The program consists of (48) training sessions held at a rate of (10) sessions per week, where the duration of the session is divided into two lessons (35) minutes to explain the daily lesson, and (35) minutes to solve the problem in a creative way using the principles of (TRIZ) theory. The program includes several educational activities and activities to solve different problems of daily life situations that the student is exposed, experiencing a problem in our lives and working to produce a creative solution by applying the creative strategy used in the course through dialogue and discussion, brainstorming, teamwork and feedback among students to develop creative thinking skills.

This program will be applied within the educational units of science for the sixth grade in schools of intellectual education, namely: Light and Sound - Human and the universe - Human and Oil.

This program is based on training students to solve problems in creative ways through sessions that include several diverse activities. Each session includes the following:

12.1 Preparation:

Students are welcomed, asked about their conditions, and given an alert before the beginning of the lesson as an activity or game that is related to the session, within 5 minutes of each session.

12.2 Presentation:

In which the daily lesson is explained and a group discussion is held with the students and some questions are asked

about the topic of the lesson within (10) minutes, and thus the students are distributed to their selected groups to start presenting the creative strategy, explaining it and giving some examples around it, and thus the problem is presented to be solved using the creative strategy, explaining and highlighting its aspects within (15) minutes, and therefore the students engage in dialogue and discussion to formulate and identify the problem within (5) minutes, and therefore the teacher asks the student groups for cooperation and discussion to develop an ideal solution to the problem within (5) minutes, Then each group proposes several suitable solutions to the problem using the creative strategy within (10) minutes. At the end of the presentation, all the solutions proposed by the student groups are displayed on the smartboard using the iPad to evaluate them and make a vote based on several criteria to choose the best one, within (10) minutes.

12.3 Final steps:

in which activity related to today's session is done, such as a stereoscopic design, a booklet, an awareness brochure, a guide board, a brainstorming for creative solutions, feedback on what has been discussed, and homework is given to students related to the content of the session. within (10) minutes.

For more details, a detailed explanation of the session has been provided (Fig. 1a, 1b, and 1c.).

13. Study Results

13.1 The results of the first hypothesis

The results related to the first hypothesis, which states that "there are statistically significant differences at the level (0.05) between the mean ranks of the experimental group's scores in the pre and post-tests on the Torrance test of creative thinking in the formal image (B) in favour of the post-test".

To verify the validity of the first hypothesis, the arithmetic averages and standard deviations of the scores of the experimental group on the Torrance test for creative thinking were calculated in the pre and post-tests, as shown in Table No. (2)

Lesson Model

Session 11 Eleven
How do we hear sounds?

Educational methods and techniques used:
I pad
plastic cups
wooden box
Plastic Colored Balls
Pens
Animal pictures

Teaching methods
Dialogue and discussion
ask questions
Brainstorming
Teamwork

General Objective	Learn how to hear sounds
Special Objective	The student knows how to hear sounds
Strategy Objective	That the students understand the strategy of merging / linking
Thinking Skills	Fluency, originality
Social Skills	Communication, teamwork
Day and Date	

Fig. 1a Lesson model

Session steps and time	Behavioral Goals	Activities and Procedures	Skill	Teaching Methods	Calendar
preparation **5 Mins**	the students be able to determine the correct number through hearing.	A circular circle is made with the students and the teacher greets them and asks them about their conditions and how their day was. The session begins with a game that knows the number by listening only where the teacher puts several balls in a wooden box and makes a sound for the balls to fall inside the box and ask the students to close their eyes and focus by hearing how many balls are in the box, the group that guesses the most correct number is the winner. (11-1)		Play Team-work	Students' interaction with the game and the accuracy of their focus in knowing the correct number
Presentation 10 Mins	the student recognizes how to hear sounds. the student knows how to maintain the integrity of his ears.	● The teacher displays a group of pictures on the smart board about the five senses of the human being, in addition to a picture of a child next to him an alarm clock, and then a discussion is held with the students as follows: (11-2) ● What made the child wake up for school? ● Which member of the head heard the alarm? ● How do we preserve this member so that he does not get sick?		Dialogue and discussion Ask questions	Students' interaction with the questions asked
Presentation 15 Mins	• the students be able to understand the strategy of merging/linking.	Problem: mocking people who can't hear (deaf). The strategy used: the merge/link strategy. The teacher explains the strategy of merging/linking, giving several examples about it in our lives, through a set of illustrations that are displayed on the smartboard. (11-3)		Dialogue and discussion	Students' understanding of the merging/linking strategy.
5 Mins	• At the end of the activity, the student should be able to derive some creative solutions to the problem using the merging/linking strategy.	Defining the problem: The students sit in their predetermined groups, then the teacher tells them a situation that happened when he visited a school and saw a group of students laughing at one of the students and the student feels upset and ashamed of the students' attitude to him and has an inquiry with the specialist about the condition of this student, he said that he is a deaf person He takes his lessons in a special class inside the school (11-4) Problem formulation: (11-5)	.	Dialogue and discussion Teamwork	Enable students to identify the problem.

			Making fun of people who can't hear (deaf).		
recess **5 Mins**			The teacher allows the students to take a short break of 5 minutes to drink water and move around a bit in the classroom .		

Fig. 1b Lesson model (continued)

Continued: Session Eleven (How do we hear sounds):

Session steps and time	**Behavioral goals**	**Skill**	**Activities and Procedures**	**Teaching Methods**	**Calendar**
5 Mins			The ideal solution to the problem: The teacher engages and discusses with the students to develop an ideal solution to the problem by using the merging/connecting strategy. Link the classes of all students in the classroom and their collective participation in activities.	Discussion Teamwork	Students are able to find an ideal solution to a problem.
10 Mins		fluency	Suggest appropriate solutions to the problem of mocking people who cannot hear (deaf people) using the merging/associating strategy: Meanwhile, the teacher moves between groups of students to motivate and encourage them to suggest appropriate solutions. : Solutions that students can suggest: • Integrate students with each other in the classroom and sports activities. • Connecting (deaf) students with normal students in friendship with the aim of helping them, getting to know them closely and supporting them. • Putting (deaf) students in one place and a specific period when providing counselling services and helping them to solve their problems. • Presenting the solutions reached by the student groups under the name of each group and writing down these solutions using the iPad on the smartboard.	Dialogue and discussion Brainstorming Teamwork	Enable students to generate as many creative solutions to the problem as possible using the merge/connect strategy.

Final steps **mines**	Design a speaker out of plastic cups and a small open tube and ask the students to distinguish the voices of their peers without seeing them by speaking through them. (11-7)	Teamwork

Fig. 1c Lesson model (continued)

Table 2. Arithmetic averages and standard deviations of the scores

	Pre-test		**test Post**	
creative skills	**Arithmetic average**	**standard deviation**	**Arithmetic average**	**standard deviation**
fluency	12.14	3.93	20.28	3.30
originality	6.57	3.77	10.00	2.70
Elaboration	3.28	487.	4.00	1.00
address abstraction (Abstractness of Titles)	2.71	1.38	5.28	2.13
Early closing resistance	4.28	3.25	7.57	3.55
Total	29.00	10.34	47.14	8.82

The Table shows that the arithmetic means in all creative thinking skills in the post-test exceeds the arithmetic mean in all creative thinking skills in the pre-test

To verify the significance of the differences between the mean ranks of the pre and post-tests, the Wilcoxon test was used for the linked samples as shown in Table No. (3)

Table 3. The results of the Wilcoxon test for correlated samples for the differences between the mean ranks of the pre-and post-test scores on the Torrance test. Figure (B)

creative skills	**ranks**	**Number**	**Mean Rank**	**Total Rank**	**Z value**	**significance level**	**effect size**
fluency	Negative*	0	00.	00.	-2.37	0.018	**0.63**
	Positive**	7	4.00	28.00			
	Equal**	0					
originality	Negative*	0	00.	00.	-2.38	.017	**0.64**
	Positive**	7	4.00	28.00			
	Equal***	0					
Elaboration	Negative*	0	00.	00.	-1.89	.059	**0.50**
	Positive**	4	2.50	10.00			
	Equal***	3					
address abstraction (Abstractness of Titles)	Negative*	0	00.	00.	-1.84	.066	**0.49**
	Positive**	4	2.50	10.00			
	Equal***	3					

Early closing resistance	Negative*	1	2.50	2.50	-1.68	.093	**0.44**
	Positive**	5	3.70	18.50			
	Equal***	1					
Total	Negative*	0	00	00	-2.36	.018	**0.63**
	Positive**	7	4.00	28.00			
	Equal***	0					

*post > pre **post < pre ***post = pre

	post-test			Follow-up test
creative skills	**Arithmetic mean**	**standard deviation**	**Arithmetic average**	**standard deviation**
fluency	20.28	3.30	22.00	3.05
originality	10.00	2.70	12.42	3.10
Elaboration	4.00	1.00	4.85	377.
Abstractness of Titles	5.28	2.13	5.57	2.29
Early closing resistance	7.57	3.55	8.85	4.01
Total Scores	47.14	8.82	53.71	9.48

The results are shown in Table (3) showed that all the students with intellectual disability in the experimental group had higher scores in the post-test, fluency and originality than the pre-test, where the value of the significance level of the degree was less than (0.05). The results also showed that the difference between the group averages in skill (Elaboration) and skill (Abstractness of Titles) between the pre and post-tests was not statistically significant.

The effect size of the training was calculated through the Z-value of the total score (-2.36), where the effect size value, which represents the percentage of variance in the creative thinking skills of students with mild intellectual disability, can be explained through the impact of the application of the program. By calculating the effect size extracted from the previous equation, showed that the program had an impact on all creative thinking skills, as the effect size was medium, which indicates that the program affected the experimental sample in all creative thinking skills.

13.2 The results of the second hypothesis

The results related to the second hypothesis, which states that "there are statistically significant differences at the level (0.05) between the mean ranks of the experimental group's scores in the post and Follow-up test on the Torrance test of creative thinking (Figure. B) in favour of the Follow-up test).

To verify the validity of the second hypothesis, the arithmetic averages and standard deviations of the scores of the experimental group on the Torrance Test for Creative Thinking were calculated (formal form (B) in the post and follow-up test, as shown in Table 4.

Table 4. Arithmetic averages and standard deviations of the scores

Table No. (4) shows that the arithmetic means of the scores of the experimental group in the post-test of the total score equals (47.14) with a standard deviation (8.82), while it reached in the Follow-up test (53.71) with a standard deviation of (9.48), where it turns out that the arithmetic averages in all creative thinking skills in the follow-up measurement, the arithmetic mean exceeded in all creative thinking skills in the post-test.

To verify the significance of the differences between the mean ranks of the post and Follow-up test, the Wilcoxon test was used for the linked samples as shown in Table 5.

Table 5. The results of the Wilcoxon test for correlated samples for the differences between the mean ranks of the post- and Follow-up test scores on the Torrance test. Figure (B)

creative skills	ranks	Number	Mean Rank	Total Rank	Z value	significance level
fluency	Negative*	0	00.	00.	2.401-	**016.**
	Positive**	7	4.00	28.00		
	Equal**	0				
originality	Negative*	0	00.	00.	2.388-	**017.**
	Positive**	7	4.00	28.00		
	Equal***	0				
Elaboration	Negative*	1	3.50	3.50	1.897-	**058.**
	Positive**	6	4.08	24.50		
	Equal***	0				
Abstractness of Title	Negative*	2	2.75	5.50	552.-	**581.**
	Positive**	3	3.17	9.50		
	Equal***	2				
Early closing resistance	Negative*	1	1.00	1.00	1.786-	**074.**
	Positive**	4	3.50	14.00		
	Equal***	2				
Total Scores	Negative*	0	00	00	2.371-	**018.**
	Positive**	7	4.00	28.00		
	Equal***	0				

* Follow-up > post ** Follow-up< post *** Follow-up = post

The results shown in Table No. (5) showed that all students with intellectual disability in the experimental group had higher scores in the Follow-up test than the post-test, where the significance level value of the total score was (018.), and it is clear that the difference between the group averages in the skill (fluency) and (originality) between the post and Follow-up tests, it was statistically significant in favor of the Follow-up test, where the significance level of the skill (Fluency) was equal to (016.), which is less than (0.05), and the significance level of the skill (originality) equaled (017.), which is less than (0.05), while it was found through the results that the difference between the group averages in the skill (Elaboration) and the skill (Abstractness of Titles) between the Sequential and post-tests was not statistically significant, as the value of the significance level of the skill (Elaboration) was (058.), which is higher than (0.05) and the value of the significance level of the skill (Abstractness of Titles) is equal to (581.), which is higher than (0.05), and it was also shown through the results that the difference between the group averages in the skill (early closure) between the Sequential and post-tests was not statistically significant, as The significance level value was (074.), which is higher than (0.05).

14. Discussion & Interpretation of Results

The results of the first hypothesis indicated that there are statistically significant differences between the mean scores of the research sample members in the pre and post-tests on the Torrance test of creative thinking, the formal image (B) in favour of the post-test as shown in Table No. (5), and according to the data recorded in the table, it is clear The performance of the group improved on the post-test over the pre-test, and the reason for this is due to the existence of the effect of (TRIZ) program on the sample members and the development of their creative thinking skills than they were before the start of the program.

The strategies used in the (TRIZ) program had a clear role in improving students' level of creative thinking and problem-solving skills, which are (Segmentation, Combining / Merging, Inversion), as these strategies changed the students' thinking pattern and their interaction in creatively solving daily life problems, developing this thinking and motivating them to be creative and discover their latent abilities, and this was also shown by increasing the level of self-confidence among these students that they are individuals capable of facing and solving problems in creative ways, as various teaching methods were applied to work on extracting these creative ideas represented in dialogue, discussion, asking questions, brainstorming, and posing problems to develop creative thinking, teamwork, play, feedback, and homework.

In addition to, the use of various educational means to communicate and clarify information using the (TRIZ) program strategies to develop creative thinking, among the means that were used are the tablet (iPad), explaining the lesson and the problem through pictures, video, and the short story, conducting scientific experiments with students, and deliver all the activities, tools and projects we focus on in the daily sessions to the students' homes. To provide all the requirements of the daily session for them to interact and participate, in particular, spherical models of cork were provided for the shape of the earth and the moon, coloured clay and moulding tools for making the different faces of the moon, and coloured cardboard for the design of the traffic light, and whiteboards for the design of guiding and awareness means to save electrical energy, to raise awareness of the safety and security instructions at the petrol station, a picture booklet, a gift box for decoration, coloured beads, coloured ribbons, plastic cups for making telephone headsets, wooden sticks

for making a compass shape, pens, wooden and wax colours, glue and adhesive, and these activities and the supporting means that were provided to all The students contributed to the development of the creative thinking skills of the research sample.

And this has made the students more creative, where the teacher explains the daily lesson and asks questions, so we connect the life problem to the lesson of the day itself, and explain what creative strategy we're going to solve the problem and explain several examples of it. The teacher, therefore, asks each student to explain the examples of the strategy so that they can be recognized and understood as to how to solve the problem facing us and to come up with creative ideas by solving the problem with the strategy of the session. At the end of the session, we make a concluding activity related to the session itself to develop creative ideas, such as"(making a stereoscopic and adding Elaborations to it, developing many diverse ideas for a topic or a shape, making an awareness poster that includes various creative ideas, and developing additional diverse solutions to today's problem using the creative strategy, where These activities helped them acquire creative thinking and problem-solving skills, which increased their life knowledge and self-confidence and changed their thinking style towards looking at things.

The improvement in the level of students can also be explained by the fact that the researcher was able to have a good professional relationship based on respect, acceptance and understanding the needs of students with intellectual disability. by creating and developing good manners among the students through competition between them and helping each other in solving problems, gaining the skills of perseverance, self-initiative and developing a spirit of teamwork and cooperation among the students. This is what the researcher sought during the formation of the professional relationship with the students and even during the daily sessions, where they were encouraged to participate, initiative, cooperation and teamwork, which boosted the students' self-confidence and this was demonstrated through the subsequent sessions of good interaction and expression of themselves and breaking the barrier of shyness and fear of learning Something new in their lives leads to a high level of confidence and thinking from the beginning of solving the first problem to the end of the program sessions.

What helped the students' interaction continuously was that the researcher activated the enhancement by making a behavioural contract with the students and making an enhancement board, where the researcher indicated to the students that there is an honour for them in the morning assembly after completing the training program, and the creative student who will be honoured is the one who has proven his presence in the program through his interaction, and active participation, good behaviour and manners, respect for the laws and ethics of the classroom, and the rules of the training program. I called to them the Creator Program, and they, in turn, called it Creative Strategies. In addition to the behavioural contracting, the researcher used various enhancements methods such as the star enhancement board, where the student who interacts during the session gets a star and if he collects 5 consecutive stars he would get a token gift at the end of the week, which helped the students interact well and strengthen them morally with words of encouragement, that enhance their self-confidence. The researcher presented their achievements to their parents who had an important role in the program through cooperation and participation in preparing the student's tools such as a computer or tablet (iPad) and entering the session on the Zoom program, where the researcher trained some parents on how to log into the program and enter the daily sessions and giving instructions to parents to prepare the tools for the

session and create the appropriate place at home.

In addition, the success of the (TRIZ) program in developing the creative thinking skills of the sample members can be explained by range of topics that were presented that were raised in the training sessions and which were linked to the realities of students with intellectual disability, in how to face and solve daily life problems, through focusing on training these students to be able to identify and formulate the problem, to develop an ideal solution to the problem and to enable them to, and enable them to develop the largest number of creative solutions to the problem using the TRIZ program strategies to solve problems in creative ways, and thus choose the appropriate solution through the various solutions that they presented, and this What was shown by the high level of students in creative thinking skills in (fluency skill and originality skill) in producing creative ideas and solutions, and the high level of some students in the rest of creative thinking skills in (Elaboration skill, Abstractness of Titles skill, and early closure resistance skill), as (3) students were their scores are equal in the pre and post-tests in the skills of Elaboration and Abstractness of Titles, one student did not raise his level in the skill of resisting early closure, which led to the lack of statistical significance in this skill. The results of the current research in the total score indicate the existence of an effect of the program ((TRIZ) program), which amounted to (0.63). and indicating the existence of a mean effect of the program on the research sample are students with mild intellectual disability.

This is consistent and agrees with (Cote et al, 2010) study, which indicated that all students with mild intellectual disability learned how to identify the problem, how it can be solved and find possible solutions, in addition to generalizing and applying their skills in solving problems, as well as consistent with (Fard et al, 2014) study, The program based on solving problem led to the development of creative thinking skills in fluency, flexibility, originality and Elaboration among students with mild intellectual disability, and the results of the current research agreed with the study (Lant, 2019). Which showed the positive role of the problem-solving strategy in integrating it with the daily lessons for students with mild intellectual disability, in addition to the role of support and encouragement for students enhancing their self-confidence when facing new problems and it led to showing the creative ideas and skills of the sample members.

The results of the current research showed the positive role of the (TRIZ) program in developing creative thinking and problem-solving skills for students with mild intellectual disability, as it added the results of the current research with studies that applied the strategies of the (TRIZ) program with different age groups and different groups students with special needs, such as a study on talented children, a study on children with learning difficulties, and a study on students with hearing disability in the educational field, as these studies showed effective positive results in developing their creative skills and abilities, proving that the (TRIZ) program is not limited to a specific age or a category without another, but any individual can be trained on it to develop creative thinking skills and solve problems in creative ways, and this is done through the good use of (TRIZ) program strategies and integrating with the educational curriculum, and this is what was done by integrating some of the strategies of the (TRIZ) program with the educational curriculum for science for the sixth grade of primary school of intellectual education in the State of Kuwait.

The results of the second hypothesis also indicate that there are statistically significant differences between the mean rank scores of the research sample members in the post and follow-up test on the Torrance test of creative

thinking, the formal Figure (B), where the follow-up measurement was applied two weeks after the end of the training program for the sample members, and it determines that there are statistically significant differences between the post-test and follow-up of the Torrance test of creative thinking (formal image (B) in favour of the follow-up measurement in the skill of fluency and originality skill and the total score. on different types of problems they face, and this is agreed with the study (Karabulut & Ozmen, 2018) through the positive impact of the problem-solving program and the students' acquisition of that skill and its generalization to different types of problems they face in their lives, and this can be explained because of the continuing impact of the training program which contained 24 various training sessions in solving problems we face in our daily lives related to the science curriculum, and also as a result of using methods and different techniques and teaching methods appropriate to the research sample and the age stage, all of this led to the sample members retaining the skills they acquired after two weeks of post-test and generalizing these skills in their daily practices, as the activities used in the training program varied between fluency development and fluency development activities. The skill of originality in producing original creative ideas and solutions, activities that develop the skill of Elaboration in adding details to a problem or a specific activity, and activities that develop team and cooperative work, interaction and communication with their colleagues. People with intellectual disability are encouraged to change the programs offered to them and the importance of those training programs that develop creative thinking and problem-solving skills and integrate them into their educational curricula.

15. Conclusions

In this research aims, TRIZ is applied to develope creative thinking skills (Fluency, Originality, Elaboration, Abstractness of Titles, Resistance to Premature Closure) by integrating some of (TRIZ) strategies into the science curriculum for sixth grade in schools of intellectual education among male students with mild intellectual disability, this strategies showed that TRIZ program had a clear role in improving students level of creative thinking and problem solving skills, which are (inversion / inversion), (merging / linking) and (dividing / segmentation), as these strategies changed the pattern of thinking Students and their interaction in solving daily life problems in a creative way, developing this thinking and motivating them to be creative and discover their latent abilities, future research can also be focused and discover that the TRIZ program is not limited to a specific age or group without another, but it is possible to train any individual on it to develop creative thinking skills and solve problems in creative ways. It was implemented by integrating some of the strategies of the TRIZ program with the educational curriculum for the sixth-grade science subject for schools of intellectual education in the State of Kuwait, and that what we need for the educational field for people with intellectual disabilities to change the programs offered to them and the importance of those training programs that develop creative thinking and problem-solving skills and integrate them into their educational curricula.

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A Digital Maturity Model for Organizations: An Approach to Assessment and Case Study

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Abstract

The issues of digital transformation and digital maturity have continued to be relevant over the past few decades. It is difficult to state that there is a universal digital maturity model (DMM) simultaneously applicable for organizations, industries, regions, and countries. We have tried to develop a universal DMM. It is based on the assessment of the digitalization level of the core business processes, including internal and external. The model includes 5 levels. We tested the DMM on 126 organizations. The results showed that 45% of the organizations belong to the second level ("partial digitalization"). The advantages of the model are simplicity of use, applicability for organizations of different sizes and forms of ownership, and a relatively high degree of objectivity. Further testing of the DMM will be aimed at assessing the level of the digital maturity of industries and regions.

Keywords: Digital maturity model, digitalization, digital transformation.

1. Introduction

Digital transformation is a process that has affected all sectors of our society (Galindo-Martín et al., 2019; Shen et al., 2018). Most researchers consider it as a tool for improving the efficiency of the businesses by optimizing business processes, reducing operating costs, increasing the understanding of the customer experience, developing the professional competencies of employees, and enhancing the level of the corporate culture (Bellakhal and Mouelhi, 2020; Martín-Pena et al., 2019; Nambisan et al., 2019). In addition, digitalization forms a completely new approach to management (Díaz-Chao et al., 2015; PwC, 2016). Digital technologies have become the basic determinants of competitiveness (Bertani et al., 2021; De Pablos and Edvinsson, 2020) and help to increase the value of companies (Salvi et al., 2021).

A lot of studies related to digitalization and digital transformation have appeared in the last decade. The number of papers on it has been growing rapidly from year to year (Reis et al., 2018). The researchers explore different aspects (for instance, the capabilities of different Information and Communication Technologies (ICTs), digital skills, effectiveness of ICTs, new business models, etc.) and levels (for instance, digitalization of countries, regions, cities, sectors, and organizations) of this phenomenon (Santoalha et al., 2021; Ballestar et al., 2021; Kijek and Kijek, 2019; Kraus et al., 2019; Yang et al., 2021).

Some studies try to evaluate the level of digitalization and to provide a vision for future development. In other words, the researchers try to measure digital maturity. As a result, a large number of digital maturity models (DMMs) have appeared in recent years (DESI, 2021; UK Consumer Digital Index, 2021; Grebe et al., 2021; Dell Technologies, 2018; Berghaus, 2016; Friedrich et al., 2011; Westerman, 2012; Berger, 2015; Gill andVanBoskirk, 2016; Valdez-de-Leon, 2016; Salviotti et al., 2019; Ifenthaler and Egloffstein, 2019). The models are based on the analysis of the certain groups of the criteria. Each of them has its strengths and limitations. However, several common gaps can be highlighted. Most of these models can hardly be regarded as universal, i.e., at the same time applicable for organizations, sectors, regions, and countries. The other limitation of some DMMs is the subjectivity of evaluations and application complexity. Besides, usually, DMMs have been developed by practice-oriented consultants. As a result, this fact limits the existence of their theoretical basis (Thordsen et al., 2020). Thordsen

et al. analyzed 17 existing DMMs and noted that they do not have enough measurement validity.

In this context, the study tried to develop a new DMM which will be characterized by the following features: universality (i.e., applicable for organizations, industries, regions, and countries), maximum objectivity, theoretical basis and easy handling.

To develop the model, we made a literature review in the context of (1) the theoretical understanding of digitalization and Information and communications technologies (ICTs), (2) the existing DMMs including criteria for measurement, and (3) exploring the role of business processes in the digital transformation of the enterprises. At the next step, we designed our DMM and tried to conceptualize it theoretically. We also tested it on 126 organizations.

As a result, we concluded that the developed DMM operated with only objective criteria – the fact of the implementation of the specialized ICT in the key business processes of the organizations. Besides, the DMM can be applied for the levels of sectors, regions, and countries.

2. Literature Review and Theoretical Background

2.1 The Concept of Digitalization

Currently, there are many variants of the definition of digitalization (digital transformation). For example, Stolterman and Fors (2004) have noted that digitalization is a business model driven by changes associated with the application of digital technology in all areas of human society. Gassmann et al. (2014) have got the alternative definition of digital transformation: it is the ability to transform existing products or services into digital counterparts and thereby create advantages over tangible products.

In their literature review, Emily et al. (2015) have identified four main aspects of digitalization: digital capacity, business models, operational processes, and ICT user experience.

Several scientists have identified key types of technologies that underlie digital transformation. They include cyber-physical systems, smart factories, digital twins, the Internet of Things, big data, artificial intelligence, and cloud computing (Liao et al., 2017; Brynjolfsson and McAfee, 2014; Schwab et al., 2018; Li, 2018; Xu et al., 2018; Roblek et al., 2016).

Rossato and Castellani (2020) analyzed some companies and concluded that digitalization has the following positive effects: increased efficiency of business processes, improved understanding of the customer experience, developed professional competencies, and improved corporate culture.

Emily et al. (2020) suggested that such evolution can bring competitive advantages to a company in the form of more efficient business processes and, consequently, higher performance.

One of the key features of digitalization is the capacity to change and transform an organization's business processes and ecosystem (Legner at al., 2017; Parviainen at al., 2017).

Much less research has been devoted to quantifying the impact of digitalization on business development. In particular, Calvino and Criscuolo (2019) conducted statistical analysis for 15 different countries. As a result, the researchers concluded that technological factors provide positive dynamics for business development with an average 40 percent. At the same time, there are significant differences between countries in the dynamics of high-tech industries. It is associated with institutional and political factors.

Some researchers noted that digitalization has become a strategic priority for many companies, but their movement in this direction is rarely a simple process (Legner at al., 2017; Zangiacomi at al., 2020).

The digital transformation is inextricably linked to government policy. The most frequently mentioned one is the German government program “Industry 4.0”. At the same time, similar initiatives have been launched in other countries. For example, “Made-in-China 2025” in China, “Industrial Internet and Smart Manufacturing” in the US, “Intelligent Manufacturing Systems” in Japan, “Factories of the Future” in the EU, and “Future of Manufacturing” in the UK (Liao et al., 2017; Schneider, 2018). The underlying approaches and ideas of these programs are at the intersection of many disciplines, including electronics, business and management, computer science, business and information systems engineering, and mechanical engineering (Lasi et al., 2014).

Companies involved in digital transformation not only gain opportunities to add value to their products and services but, more importantly, bring radical changes to their business models (Köbnick, 2020).

At the same time, the changes in business models associated with digitalization lead to additional risks. Thus, Kovaitė and Stankevičienė (2019) distinguish six types of such risks at the micro-level: technical, competence, accepted by personnel, accepted by customers and partners, financial, and data privacy and security.

Many organizations report success in their digitalization or at least declare their intentions to start the

process (Galindo-Martín et al., 2019). Therefore, organizations need to understand both their current level of digitalization and to set the right goals for moving forward on this path. We suppose it is the key point of "true/real" digital transformation for achieving more efficiency.

2.2 Review of Digital Maturity Models

Digital maturity is the term that shows the current level of the organization's digitalization (Chanias and Hess, 2016). Thordsen et al. (2020) analyzed 17 DMMs. The authors noted a lot of differences between the models. First of all the DMMs used different indicators to measure the level of digitalization. Nine of the analyzed models do not provide any theoretical base. In most cases, developers of DMMs do not provide any arguments in terms of the general logic theory.

In addition to the 17 DMMs that have been analyzed by Thordsen et al. (2020), we consider more models.

In our opinion, the most comprehensive approach to the digital maturity assessment is the Digital Economy and Society Index (DESI) (DESI, 2020). It is developed by the European Commission and used to assess the level of digitalization of the EU countries. The calculation of this index is based on the evaluation of indicators included in 5 main subindexes: (1) availability and quality of communications (including the level of use of fixed broadband access and its coverage, mobile broadband access, and the level of prices for broadband access), (2) human capital (including the level of digital skills of the population), (3) level of Internet penetration among the population, (4) level of ICT used by business, (5) level of public services provided in digital form.

For our study, the subindex (the level of ICT used by business - Digital Intensity Index) deserves special attention. It is based on the following indicators: using information security systems in business, staff awareness of information security requirements, maximum Internet connection speed at least 30 Mb/s, using ERP system, using at least one social network, using CRM system, over 50% of employees use computer and Internet at work, over 20% of employees use portable gadgets in their work and sales in an online format. Each of these indicators is calculated as a percentage of the total number of surveyed organizations, separately for large and small-medium businesses.

Some DMMs characterize certain aspects of the digitalization process. One of these indicators is the Digital Capital Index (Ragnedda et al., 2019). The index is socially focused. It shows the readiness of the population to interact effectively with ICT.

One more DMM is the UK Consumer Digital Index (2021). This index has been used for the last six years to assess the level of ICT usage by the UK population. The Index is based on a structured survey of residents of the country. The questions include 3 blocks: (1) how a person makes payments, (2) how a person uses digital services and products, and (3) how digital technology is used in daily life. The Index values are ranked in four levels: (1) very low (a respondent does not use an email or a personal computer), (2) low (a respondent uses an email and has a personal computer), (3) high (a respondent uses online banking and uses various online services), and (4) very high (a respondent uses various online services and makes payments online very often).

The Digital Acceleration Index (DAI) (Grebe et al., 2021) measures an organization's digital development in 36 categories, such as customer journey, digital supply chain, and personalization of marketing. Unfortunately, more information on the methodology of this Index is not publicly available.

The Digital Transformation Index (Dell Technologies, 2018) is based on surveys of companies from various business areas. Based on the results a respondent can be classified in one of five groups: "Digital laggards" (such organizations have no plan for digitalization, changes in digital technologies and investments in them are very rare), "Digital followers" (investments in ICT are not significant, there are preliminary plans for digitalization), "Digital professionals" (they implement a gradual digital transformation and there is the planning of this process), "Adherents of digitalization" (a detailed plan for digital transformation is developed, relevant investments are allocated) and "Digital leaders" (digitalization is the basis of corporate culture). The DMM takes into account both the current level of digitalization and the future development plans. The model uses a mix of qualitative and quantitative indicators.

We made a content analysis of the selected DMMs by their core elements (table 1).

Table 1. Content Analysis of the Selected DMMs

Name of the DMM	Dimensions of the assessment	Criteria of the assessment	Method of the assessment	Object of the assessment	Source of the data	Result of the assessment
Digital Economy and Society Index (DESI) (DESI, 2020)	5 dimensions: connectivity, human capital, use of internet, integration of digital technology, digital public services	Set of statistical indicators corresponding to the dimensions	Quantitative	Countries	Eurostat data	Total score
UK Consumer Digital Index (2021)	3 dimensions: digital payments, digital services, digital technology in daily life	Set of questions corresponding to the dimensions	Structured survey	Population	Population	four levels: very low, low, high, very high
Digital Transformation Index (Dell Technologies, 2018)	4 dimensions: IT strategy, digital future, competition, investment	Set of questions corresponding to the dimensions	Mix of qualitative and quantitative (online-questionnaire based on 6-step Likert-scale)	Organizations	Management of organizations	5 groups: digital laggards, digital followers, digital professional, adherents of digitalization, digital leaders
Digital maturity and transformation report (Berghaus and Back, 2016)	9 dimensions: customer experience, product innovation, strategy, organization, process digitization, collaboration, information technology, culture and expertise, transformation management	60 criteria (e.g., experience design, business segment extension, strategic innovation, etc.)	Quantitative (online-questionnaire based on 5-step Likert-scale)	Organizations/ sectors	Management of organizations	5 maturity stages: promote and support, create and build, commit to transform, user-centered and elaborated processes, data-driven enterprise
Industry digitization index (Friedrich et al., 2011)	4 dimensions (across business process): input, processing, output, infrastructure	Volume of investments in ICT, digital services for customers, value chains, computing infrastructure	Quantitative (no detailed description is provided)	Sectors	Eurostat data	Total score
Digital maturity matrix (Westerman et al., 2012)	2 dimensions: digital intensity, transformation management intensity	3 groups: customer experience, operational process, business model	Qualitative (interview)	Organizations	Management of organizations	4 groups: beginners, conservative, fashionistas, digirati
Digital transformation index (Berger, 2015)	4 dimensions: digital data, automation, connectivity, digital customer access	The question: what is the current level of digital maturity of your organization?	Qualitative (self-assessment)	Organizations	Management of organizations	3 levels: very high, high, low
Digital maturity model 4.0 (Gill and VanBoskirk, 2016)	4 dimensions: culture, technology, organization, insights	28 questions (corresponding to the dimensions)	Quantitative (interview based on 4-step Likert-scale)	Organizations	Management of organizations	4 maturity segments: skeptics, adopters, collaborators, differentiators

Name of the DMM	Dimensions of the assessment	Criteria of the assessment	Method of the assessment	Object of the assessment	Source of the data	Result of the assessment
Digital maturity model for telecom (Valdez-de-Leon, 2016)	4 dimensions: strategy, organization, customer, ecosystem, operations, technology, innovation	126 questions (corresponding to the dimensions)	Qualitative (the Delphi method)	Telecom organizations	Management of organizations	6 levels: not started, initiating, enabling, integrating, optimizing, pioneering
Strategic factors enabling digital maturity (Salviotti, Gaur and Pennarola, 2019)	10 dimensions: IT infrastructure, human resource management, research and development, administration, finance and control, procurement, inbound logistics, operations, outbound logistics, marketing and sales, post-sales services	10 questions (corresponding to the dimensions)	Quantitative (interview based on 5-step Likert-scale)	Organizations	Management of organizations	Total score
Maturity model of technology (Ifenthaler and Egloffstein, 2019)	6 dimensions: infrastructure, strategy and leadership, organization, employees, culture, and educational technology	22 questions (corresponding to the dimensions)	Quantitative (interview based on 5-step Likert-scale)	Educational organizations	Management of organizations	5 levels: digitally minimalist, digitally conservative, digitally pragmatist, digitally advanced, digitally trailblazing

Thus, the reviewed DMMs considerably differ in the following ways:

(1) By the approach. The quantitative one is dominant.

(2) By the object. The level of organizations is prevailing.

(3) By the vision. A combination of descriptive and prescriptive visions prevails.

Researchers note the following advantages of the models: (1) an objective performance assessment (i.e., maturity level) (De Bruin et al., 2005; Lahrmann and Marx, 2010), (2) the base for a roadmap to increase the digital level in the future (Mettler and Rohner, 2009), and (3) comparison and benchmarking with other organizations (Berghaus and Back, 2016).

The disadvantages of the DMMs are (1) the lack of suggestions to improve the current maturity level (Berghaus and Back, 2016) and (2) the lack of attention to human resources and too much focus on organizational processes (Poeppelbuss et al., 2011). Besides, we note that there is some subjectivity in the most of reviewed DMMs. For example, when a respondent is asked about a certain aspect of digitalization of his organization, the answers "we are planning" or "we have just started" are taken into account. In our view, there is a risk that the respondent may slightly "sugarcoat the picture" when, for example, the answer "we plan" will be realized only after a few years.

That is why we plan to find more objective dimensions and criteria for assessing digital maturity. And we hypothesize that it is the business processes of organizations.

2.3 Digitalization and Business Processes on Micro-Level

The above literature review allows us to argue that at the micro-level digitalization is inextricably linked to changes in business processes. In particular, Gates and Hemingway (1999) noted that ICT is a powerful tool for business process management and business transformation.

Appel et al. (2014) found that business process modeling and execution are widespread in various enterprises. Business experts are simulating processes and translate them into executable work operations.

Davenport (1993) defined a business process as a structured and measurable set of activities designed to achieve an outcome for a particular customer or market. It shifts a focus from the end product to an assessment of work quality. In other words, a business process is a specific sequence of work activities in time and space, with a beginning and an end, and clearly defined resources and results expressed in an action plan.

There are several classifications of business processes in the literature. Usually, they have many common attributes (Earl, 1994; Edwards and Peppard, 1994; Rockart, 1988). Thus, Earl's classification (Earl, 1994) is the most capacious. It summarizes the main ideas of other researchers. This classification identifies four types of business processes according to their role in the value chain:

1. The core business processes ensure the main activities of the organization. They are directly related to the service of external customers. Usually, they are the main part of the value creation process.

2. Supporting processes include servicing internal customers. They imply the performance of auxiliary activities. Typically, these are processes related to the administration of the organization's core activities.

3. “Business environment” processes go beyond the organization. They involve organizing interactions with suppliers, clients, and partners.

4. Management processes include planning, organizing, and controlling the organization's activities.

Singh (2012) highlights that a typical organization should have no more than 15 core business processes. They will depend, among other things, on the scope and objectives of the organization.

Consulting company AchieveIt (2014) identifies three types of business processes: (1) management processes, including corporate governance and strategic management, (2) operational processes (for example, in an industrial company they are purchasing, manufacturing, marketing, and sales), (3) supporting processes, including accounting, human resources, and information technology.

Dickmann (2019) offers a similar classification. He distinguishes three categories of business processes:

1. Primary processes, which include operations such as production, marketing, and sales. These processes are designed to provide an external customer with an added value based on the delivery of products and services.

2. Secondary processes do not directly provide an external customer with added value. But they are vital for the existence of the organization. They support the smooth functioning of the primary business processes and contribute to the smooth workflow of the business. Such processes are implemented, for example, in the accounting department, human resources department, and helpdesk.

3. A management process includes planning, monitoring, and controlling the activities of the organization. Examples of such business processes are internal communications, budgeting, and infrastructure operations.

For further study, it is important to understand what core business processes are. Thus, the Quality Management System Standard ISO 9001 (2017) gives the next definition: core business process (Core process) is a process that is strategically important for the company. Core processes are characterized by the following aspects: (1) they create value, (2) the external customer is at the beginning and at the end of the process, (3) they make a significant contribution to the success of the company and customer satisfaction, (4) they are directly related to the customer and have a direct impact on the customer, and (5) the customer is willing to pay for the result of the process.

Typically, the researchers identify five to ten major business systems and corresponding business processes. Among them are the next (The New Paradigm Team, 2021; Bizmanualz, 2021):

1. Marketing strategy and customer relations.
2. Attracting customers (sales).
3. Development and satisfaction of the employees (human resource management).
4. Information technologies.
5. Quality management, process improvement, and change management.
6. Product manufacturing.
7. Logistics.
8. Accounting.
9. Financial management and management accounting.
10. Strategic management.

Business processes materialize in various forms, including technology, product development, employee training, customer service, etc. (Dickmann, 2019).

As a result of the literature review, we conclude that despite DMMs variety there is no universal approach. Each model has some advantages and disadvantages. Each DMM assesses the stage of digitalization at a certain level: company, sector, region, or country. Models based on qualitative assessments are more subjective because the results depend on the willingness of respondents to show the real picture of their business.

According to these conclusions, we tried to develop a universal methodology i.e., allowing to measure the digital maturity for organizations, industries, regions, and countries. The model should be based on the most objective dimensions and criteria.

3. Methodology

3.1 Design of the Digital Maturity Model for Organizations

As we tried to show above, digital transformation primarily affects the business processes of

organizations. That is why our DMM is based on an assessment of the implementation of the specialized ICT in the key business processes. In doing so, we do not consider as specialized ICT widely used software, such as Word, Excel, e-mail, etc.

The literature review helped us to distinguish six groups of key business processes that are typical for most organizations. Each of the groups includes some relevant key business processes (appendix 1). We have identified groups of business processes on a functional basis. Together they include all types of business processes according to the above-mentioned classifications.

The core element of our DMM is the specially designed questionnaire (appendix 2).

During the interview process, we sequentially asked the respondents a series of questions concerning each business process. Each answer is transformed into a point (1 or 0) (figure 1).

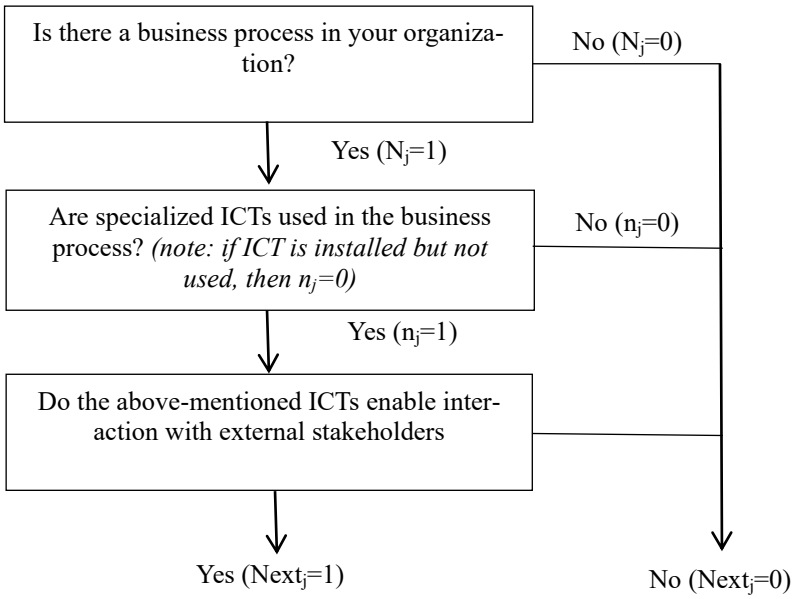

Figure 1. Structured Questionnaire and Score for the Answers

Then we calculated the levels of digitalization of the internal and external business processes separately. We made it using the following formulas:

$$LoD_{int} = \frac{\sum n_j}{\sum N_j} * 100\% \quad (1)$$

LoD_{int} – the level of digitalization of the internal business processes in the organization;

n_j – the key business processes that use specialized ICTs;

N_j – the key business processes that exist in the organization.

$$LoD_{ext} = \frac{\sum Next_j}{\sum N_j} * 100\%$$

LoD_{ext} – the level of digitalization of the key business processes with external stakeholders;

$Next_j$ – the key business processes that use specialized ICTs in interactions with external stakeholders;

N_j – the key business processes that exist in the organization.

As a result, we can classify the organization into one of the five levels of digital maturity (figure 2). The evaluation criteria are shown in table 2.

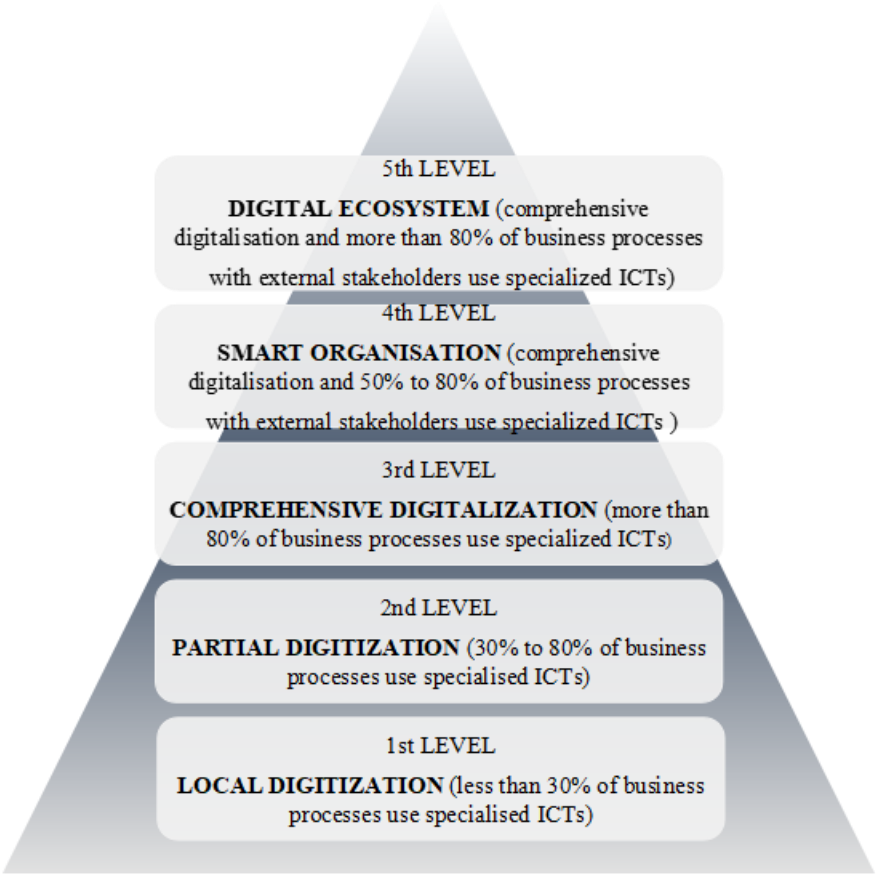

Figure 2. Levels of Digital Maturity of an Organization

Table 2. The Evaluation Criteria for Classifying the Organization into One of Five Levels of Digital Maturity

		Digitalization of the key business processes with external stakeholders		
		Less than 50% of the key business processes with external stakeholders use specialized ICTs	50% to 80% of the key business processes with external stakeholders use specialized ICTs	More than 80% of the key business processes with external stakeholders use specialized ICTs
Digitalization of the internal key business processes	More than 80% of business processes use specialized ICTs	COMPREHENSIVE DIGITALIZATION	SMART ORGANISATION	DIGITAL ECOSYSTEM
	30% to 80% of business processes use specialized ICTs	PARTIAL DIGITIZATION	-	-
	Less than 30% of business processes use specialized ICTs	LOCAL DIGITIZATION	-	-

3.2 Questionary Survey

The study was carried out from September 2020 to July 2021. We used a questionnaire (appendix 2) to conduct structured interviews. The respondents were the top managers of the investigated organizations, responsible for the relevant business processes.

126 organizations participated in the study. The sampling was random and included organizations from various business sectors: healthcare, construction, retail and wholesale trade, manufacturing, mineral extraction, education, activities of restaurants and cafes, etc. (figure 3). 76% of respondents are small businesses, 9.8% - medium-sized businesses, and 14.2% - big businesses.

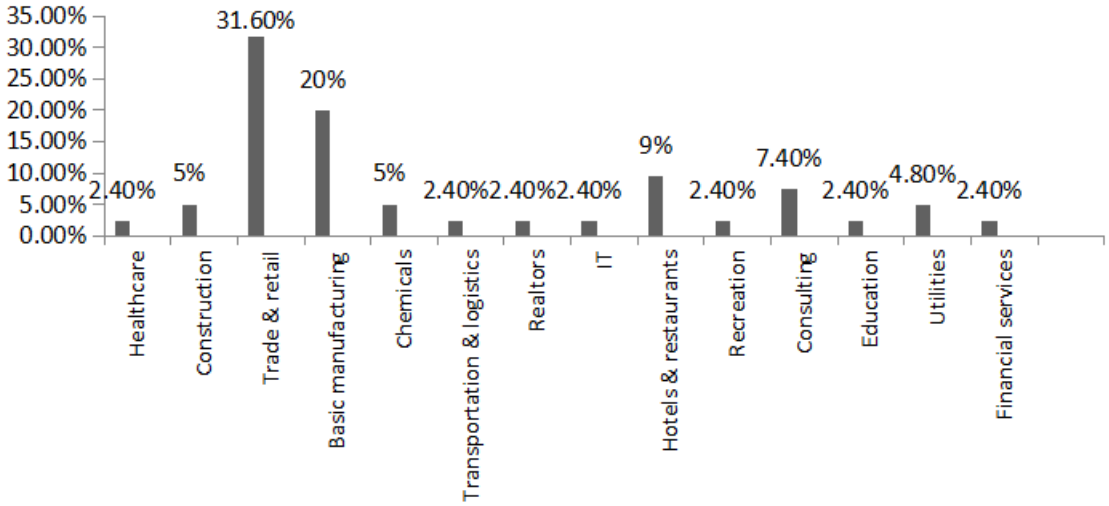

Figure 3. Spread of Respondents by Industry, Percent of Their Total Number Organizations

4. Results of the Survey

The aggregated results of the survey showed that 57 organizations (45%) have "partial digitalization" of the level of digital maturity and 26 organizations (21%) belong to the level "local digitalization" (table 3). The distribution among the small and medium enterprises largely corresponds to the above-mentioned results (table 4). Among the big businesses the third ("comprehensive digitization") and the fourth ("smart digitization") levels (table 5) dominate. We assume that the reason for this is that such organizations have more resources to implement new ICTs.

Table 3. Distribution of Total Respondents by the Level of Digital Maturity

		Digitalization of the key business processes with external stakeholders		
		Less than 50% of the key business processes with external stakeholders use specialized ICTs	50% to 80% of the key business processes with external stakeholders use specialized ICTs	More than 80% of the key business processes with external stakeholders use specialized ICTs
Digitalization of the internal key business processes	More than 80% of business processes use specialized ICTs	COMPREHENSIVE DIGITALIZATION 9.5%*	SMART ORGANISATION 4.5%*	DIGITAL ECOSYSTEM 19%*
	30% to 80% of business processes use specialized ICTs	PARTIAL DIGITIZATION 45%*	-	-
	Less than 30% of business processes use specialized ICTs	LOCAL DIGITIZATION 21%*	-	-

* the share of respondents, percent of the total respondents' number (n=126)

Table 4. Distribution of Respondents (the Small and Medium Enterprises) by the Level of Digital Maturity

		Digitalization of the key business processes with external stakeholders		
		Less 50% of the key business processes with external stakeholders use specialized ICTs	50% to 80% of the key business processes with external stakeholders use specialized ICTs	More than 80% of the key business processes with external stakeholders use specialized ICTs
Digitalization of the internal key business processes	More than 80% of business processes use specialized ICTs	COMPREHENSIVE DIGITALIZATION 5.5%*	SMART ORGANISATION 2.8%*	DIGITAL ECOSYSTEM 16.7%*
	30% to 80% of business processes use specialized ICTs	PARTIAL DIGITIZATION 52.8%*	-	-
	Less than 30% of business processes use specialized ICTs	LOCAL DIGITIZATION 22.2%*	-	-

* the share of respondents, percent of the small and medium enterprises (n=108 units)

Table 5. Distribution of Respondents (the Big Businesses) by the Level of Digital Maturity

		Digitalization of the key business processes with external stakeholders		
		Less 50% of the key business processes with external stakeholders use specialized ICTs	50% to 80% of the key business processes with external stakeholders use specialized ICTs	More than 80% of the key business processes with external stakeholders use specialized ICTs
Digitalization of the internal key business processes	More than 80% of business processes use specialized ICTs	COMPREHENSIVE DIGITALIZATION 33.3%*	SMART ORGANISATION 33.3%*	DIGITAL ECOSYSTEM 16.7%*
	30% to 80% of business processes use specialized ICTs	PARTIAL DIGITIZATION -	-	-
	Less than 30% of business processes use specialized ICTs	LOCAL DIGITIZATION 16.7%*	-	-

* the share of respondents, percent of the big businesses (n=18 units)

We also have analyzed the digitalization respondents' level of the separate groups of business processes (table 6).

Table 6. Distribution of Respondents by the Digitalization Level of the Separate Groups of Business Processes

Percent of digitalization / The group of business processes	**0%**	**1-30%**	**31-80%**	**81-100%**
Human Resources	36 (28%)	24 (19%)	21 (17%)	45 (36%)
Product and Service Provision	40 (32%)	4 (3%)	21 (17%)	61 (48%)
Marketing	60 (48%)	15 (12%)	0 (0%)	51 (40%)
Logistics	33 (26%)	18 (14,5%)	18 (14,5%)	57 (45%)
Finance and Accounting	15 (12%)	0 (0%)	39 (31%)	72 (57%)
Other Support	18 (14%)	15 (12%)	54 (43%)	39 (31%)
Totally for the internal business processes	3 (2.4%)	36 (28.6%)	45 (35.7%)	42 (33.3%)
Totally for the business processes of interactions with external stakeholders	30 (24%)	27 (22%)	36 (28%)	33 (26%)

Thus, we note some findings.

1. 31% of respondents have a low or average digital maturity level of internal business processes (i.e. 2.4% and 28.6% totally). Despite it, the same organizations have a high level of digitalization of interaction with the external environment. For example, figure 4 shows a fragment of the distribution between the first forty investigated companies.

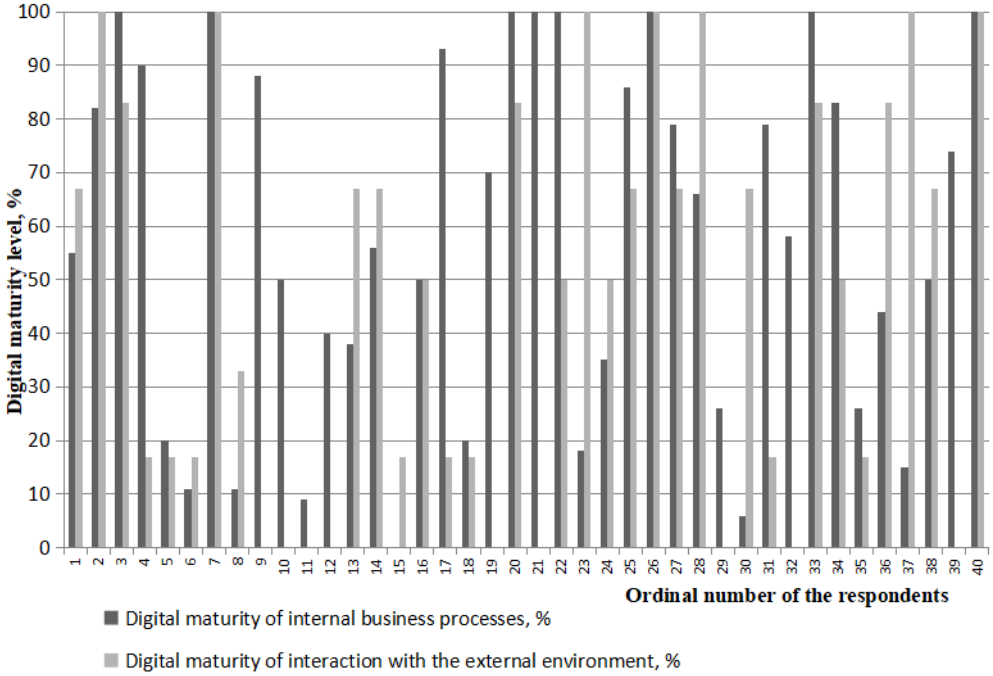

Figure 4. The Distribution of the Respondents by Internal and External Digital Maturity Level

2. Specialized ICT is most often used in the group of business processes such as (1) finance and accounting and (2) product and service provision.

3. The following groups of business processes have the largest capacity for further digital transformation: "Human Resources" (47.3% of the respondents have a low or zero digital maturity level) and "Marketing" (48% of the surveyed organizations do not use specialized ICT in the business processes).

3. We have identified some names of the frequently used (by more than ten respondents) specialized ICTs (table 7).

Table 7. The Most Frequently Used Specialized ICTs

The group of business processes	Name of the specialized ICTs
Human Resources	E-Staff, Web Tutor, Olympox*, Oracle E-Business Suite (OEBS), Dropbox, BOSS Personnel Manager*, 1C: Payroll and HR Management*
Product and Service Provision	Autocad Civil 3D, 1C:MES, 1C:Production management*
Marketing	Oracle E-Business Suite (OEBS), CRM, Bitrix24, amoCRM
Logistics	ISA-2010*, OEBS, SAR Ariba, ClientBase, 4logist, 1C: Transport Logistics*
Finance and Accounting	1C: Accounting*, OEBS, Oracle Hyperion Planning, Oracle Business Intelligence, 1C:ERP, Bitrix24
Other Support	Kaspersky Endpoint Security, Ideco UTM, Trassir, Intellect*, Max Patrol 8; FortiCate Security Fabrrie, Directum, 1C: Document Management*

* - a literal translation of the Russian software

5. Discussion and Recommendation

The testing of the DMM showed the following advantages:

- High simplicity of its implementation: (1) the structured interview allows getting the necessary information in an average of about one hour and (2) the specially structured xls-forms help to reduce the time for aggregating results.

- Top-management of the organizations can use the DMM for self-assessment. In this sense, the results can further be the basis for developing the digital transformation guidelines of the organization.

- The model can be applied to businesses of different forms of ownership, sizes, and types of economic activity.

- If we significantly increase the number of surveyed organizations (i.e. ensure representativeness), the DMM can provide the opportunity to create digital maturity rankings of industries, regions, and

countries. And that is the main direction of our future research.

- The DMM is rather flexible, i.e. if we expand and detail the number of business processes, the model will be able to reflect more detailed results.

Compared with some reviewed models, the DMM assesses only the current level of digital maturity and does not take into account the potential (readiness) of the organization for further digital transformation. On the one hand, this fact can be regarded as a disadvantage, on the other hand, it increases the level of objectivity of the study. For instance, some DMMs take into account the organization's strategic plans. So, the respondents' declaration of their plans does not always mean that these plans will be fulfilled. That is, it is important to understand that the presence of a certain "fashion for digitalization", may provoke respondents to embellish the situation.

In addition to this, in the case of repeated studies (e.g., annually), shifting in digitalization levels will indirectly confirm readiness for further changes.

The dimensions and recent criteria of most of the reviewed DMMs (DESI, 2021; UK Consumer Digital Index, 2021; Grebe et al., 2021; Dell Technologies, 2018; Berghaus, 2016; Friedrich et al., 2011; Westerman, 2012; Berger, 2015; Gill and VanBoskirk, 2016; Valdez-de-Leon, 2016; Salviotti et al., 2019; Ifenthaler and Egloffstein, 2019) can logically repeat each other. It increases the likelihood that the results of the study may be distorted (the same criteria are counted in several dimensions). For instance, installing and starting to use specialized software means the following: (1) appropriate investments have been made and (2) this is done under the strategy of the organization, (3) employees have been trained and know how to work with this software, etc. Our DMM operates only with facts answering the question: does each existing business process use any specialized ICTs or not?

We note that the question of what software to consider in the proposed model is debatable. As noted earlier, we proceeded from the fact that the use of text and table editors, and e-mail is the basic (zero) level of digitalization. That is why it is not considered in our DMM. In this regard, the next question arises. What ICTs and from what time should we exclude from the DMM. For instance, currently, the model considers cloud storage services as a specialized ICT. But the speed of dissemination of such services is quite high. Thus, perhaps soon, this ICT will be perceived as a certain basic level of digitalization.

We note that the developed DMM could be used to upgrade some other DMMs as a part of them. For instance, the Digital Economy and Society Index (DESI) can use our approach to calculate the subindex Digital Intensity Index (it shows the level of ICT used by businesses).

For our future studies we are planning to increase significantly the number of respondents. It will allow us to make rankings of the sectors and regions of our country based on the presented DMM.

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Software Defect Prediction Using Support Vector Machine

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Abstract

Software defect prediction is an essential task during the software development Lifecycle as it can help managers to identify the most defect-proneness modules. Thus, it can reduce the test cost and assign testing resources efficiently. Many classification methods can be used to determine if the software is defective or not. Support Vector Machine (SVM) has not been used extensively for such problems because of its instability when applied on different datasets and parameter settings. The main parameter that influences the accuracy is the choice of the kernel function. The use of kernel functions has not been studied thoroughly in previous papers. Therefore, this research examines the performance and accuracy of SVM with six different kernel functions. Various public datasets from the PROMISE project empirically validate our hypothesis. The results demonstrate that no kernel function can give stable performance across different experimental settings. In addition, the use of PCA as a feature reduction algorithm shows slight accuracy improvement over some datasets.

Keywords: Kernel functions, Software Defect Prediction, Support Vector Machine.

1. Introduction

Predicting defect-prone modules during the software development process is crucial because it helps the quality assurance team put more effort into modules with a high probability of defect-proneness. It also helps the management team assign and distribute resources efficiently during testing, thus reducing development costs (Wang and Yao (2013), Xu et al. (2019)). The process of manually reviewing the code usually leads to a detection rate between 35% - 60% in most cases, but this rate is in-creased when defect prediction tools are used. Furthermore, the time needed to detect defect-proneness modules is reduced (Tosun (2010)).

Software Defect Prediction (SDP) is performed by extracting static code metrics from bug log files of previous versions of the program, then using these static metrics for building models to predict the possible defects in future releases of the program (Wang and Yao (2013), Yang et al. (2014)). This process helps detect the location of the parts of the program that are likely to induce defects. It is used in a software system with a limited project budget or too large to be tested exhaustively. SDP can be primarily used in two ways: within a project or cross-project. The first approach implies using the same data as training and testing during the empirical validation process. In the second approach, one release of the project data is used as training, and the subsequent release is used as testing. Both approaches are acceptable and depend on data availability (Lie et al. (2012)).

Any SDP model comprises four main elements:1) independent features representing static code metrics, 2) output features representing the presence of a defect or its absence. 3) The learning approach, and finally 4) the performance measures that are used to judge the accuracy of the built learning model (Huda (2017)). The current studies on SDP models focus on four research aspects. The first aspect examines the importance of-static code metrics for defect prediction and which metrics are more predictive than others (Lie et al. (2012), Bowes et al. (2018), He et al. (2015), Okutan and Yildiz (2014). The second aspect focus on building

defect prediction models from within data or across data (Son et al. (2019)). The third aspect studies the effect of imbalanced data on the accuracy of defect prediction models (Wang and Yao (2013), Choeikiwong and Vateekul (2015), Sheppered et al. (2014), Sun et al. (2012)). Finally, the fourth aspect focuses on using ranking techniques to predict the correct rank of the defected modules based on their number of defects (Yang et al. (2014), Li (2011)). This study focuses on the second research aspect and attempts to study the performance of support vector machine with different kernel techniques for software defect prediction problems. Support Vector Machine (SVM) is an efficient machine leaning method that is suited for classification problems, as in our case (Hassan (2009), Kumudha and Venkatesan (2016), Chen et al. (2019)). The SVM has not been studied thoroughly in previous papers because of the instability of its accuracy over multiple datasets and it is easily influence by the choice of kernel functions (Ni et al. (2017), Ryu et al. (2019), Wei et al. (2019)). This study attempts to bridge that research gap. Different Kernel functions will be used to test the accuracy of SVM for defect prediction problems (Al-Jamimi and Ghouti (2011), Ryu et al. (2016)). This paper aims to study the impact of different Kernel functions in support vector machine for the problem of software defect prediction. Six public datasets will be used to empirically validate and test our hypothesis and assumptions. These datasets were obtained from PROMISE data repository.

The rest of paper is structured as follows: Section 2 presents related work. Section 3 presents datasets. Section 4 shows methodology of our research. Section 5 presents results and discussion. Finally, section 6 presents conclusion.

2. Related Work

Sheppard et al. (2014) examined the factors that affect the prediction of software defects. 42 studies out of 600 studies were used for the meta-analysis. The challenges were examined by the NOVA model so that the prediction process was divided into the groups: (1) Classifier family: in this group, the defect prediction techniques were divided to 7 main sections; Decision Tree, Recognition, SVM, Neural Network (ANN), Naive Bayes, CBR, Search and Benchmark. (2) Data set family: In this group, the Dataset had been divided into 24 this group, the Dataset had been divided into change or static metrics. (4) Researcher Group: There are two clusters of researchers; the most significant cluster is 8-10 researchers. The meta-analysis revealed strong evidence that current experiments in predicting defects are in-adequate and ineffective. Okutan et al. (2014) used Bayesian Network to find the relationships among metrics and defect proneness in different datasets. The PROMISE data repository used many public datasets for this experiment, such as Ant, Tomcat, Jedit, Velocity, Synapse, Poi, Lucene, Xalan, and Ivy. The static metrics used were LOC, CBO, LOCQ, WMC, RFC, LCOM, LCOM3, DIT, and NOC. Each of these datasets has a version number and instance number. The results show that the Lack of Coding Quality (LOCQ) has been evaluated as one of the best scores in the experiments.

Son et al. (2019) studied the prediction of software defects through systematic mapping and establishing a protocol for the mapping. The processes of systematic mapping have been done in four stages :(1) Application of Inclusion-Exclusion Criteria: this stage is divided into two stages Inclusion Criteria and Exclusion Criteria. Inclusion Criteria: In this stage of the study, the defect predication used software metrics provided by the analysis of statistical, search-based and machine learning techniques. Exclusion Criteria: In this stage study, the defect prediction does not use dependent variable and non-empirical nature. (2) Quality Analysis: at this stage, choose the evaluation method-ology used (3) Data Extraction: what kind of data is used (4) Data Synthesis: involves the accumulation of facts from the collected data during the data extraction process. This experiment used the techniques: Decision Tree, Support Vector Machine, Neural Network, Regression and Bayesian Learning. The Dataset was taken from different resources such as NASA, Eclipse, Mozilla, etc. The result indicated good accuracy when using a large Dataset with different metrics.

He et al. (2015) used the Dataset from PROMISE, they selected 34 releases; each one has a number of instances files and number of defects. This study used 1) several independent variables which represent the inputs that will affect the dependent variable. The study used 20 static code metrics including CK suite, Martin's metrics, QMOOM suite, Ex-tended CK suite, McCabe's CC, and LOC. 2) Dependent variables: which represents the outputs and effect, it was studied to see how much it varies as the independent variables change. It used different machine learning algorithm; in order to evaluate the result such as J48, Decision Tree, Support Vector Machine, Logistic Regression, and Naïve Bayes. The result showed that the simple metrics could be helpful to predict software defect.

Yang et al. (2014) proposed a new approach of learning to rank using the rank task. The study used 11 different types of Dataset such as Eclipse, Lucene, Mylyn, PDA and other data. The study used different method (RF, RP, BART, NBR, ZINBR, ZIPR, HNBR, and HPR) to Compare the results for the 11-datasetsusing three different metrics. The study used 10 Cross-Validation. The result showed two benefits (1) learning to rank just do rank defects and does not need to predict defects for each module (2) these expected numbers were used to predict which modules are more flawed than others in project. Wang et al. (2013) examined the problem of imbalance distribution, which may be a problem or can help to predict defect in software; through using 10 datasets from PROMISE; each one of these datasets has different number of features, different language and has a different percent of defect. This Dataset uses in different techniques in two top-ranked predictors machine learning. Naive Bayes and Random Forest and compare the result with other techniques PD, PF, balance, G-mean and AUC. The result showed that the balance and G-mean is the best result, which mean that it could use the imbalance distribution to help in predict defect.

Hassan (2009) used predict the defect of program based on the change cod of complexity. There are many processes that can be associated with code change, including the pattern of source code modification, recorded by the source control systems, and a log that saves all dates that have been changed. Statistical Linear Regression (SLR Model) was built to predict faults in subsystem. Different models and different application were used. The result showed that complex code change process negatively affects the software system, and the more complex changes to a file, the higher the chance the file will contain fault.

3. Datasets

To evaluate the effectiveness of defect prediction, we are conducting experiments on a set of data available on the PROMISE website and which have been collecting data from NASA. The data from NASA come from different project. These public datasets include the information on space craft instrumentation, satellite flight control, and ground data for storage management. In this research we will use six public datasets that are most widely used in among researchers from this repository (CM1, JM1, KC1, PC1, Class-level data for KC1version 1 and Class-level data for KC1 Version 2). Each of these datasets possesses several software modules with input as the quality metrics. the outputs of each models are whether the program is defective or non- defective. The features are divided into two main parts: McCabe and Halstead measure. This measure defines "modules" as the smallest functional units. All these datasets were developed in either C or C++ language as shown in Table 1. From Table 2, can be noted that, for all the considered six datasets, JM1, CM1, KC1 and PC1 have 22 attributes. Each of this Dataset have been including one output attributes which represent the goal of filed (defect as 1, non-defect as 0) other attributes represent the quality metrics for the project acting as input attributes. These attributes can be classified in to McCabe metrics, 9 Halstead measures, and 8 are derived Halstead measures.

Table 1. Summary of Dataset

Dataset	# Attributes	# instances	#defected	Language
JM1	22	10855	80.65%	C
CM1	22	498	9.83%	C
KC1	22	522	20.5%	C++
PC1	22	1109	93.05%	C
Class-level KC1 ver1	95	145	-	C++
Class-level KC1 ver2	95	145	-	C++

Table 2. The summary of code metrics

Quality metrics	Description
loc (v)	line count of code
v (g)	Cyclomatic complexity
ev (g)	Essential complexity
iv (g)	Design complexity
loCode	line count
loComment	Count of lines of comments
loBlank	Count of blank lines
loCodeAndComment	Count of code and comment lines
uniq_Op	Unique operators
uniq_Opnd	Unique operands
total_Op	Total operators
total_Opnd	Total operands
branchCount	Branch count of the flow graphs
n	total operators + operands
v	Volume
l	Program length
d	Difficulty
i	Intelligence
t	Time estimator
Defect	True/False

4. Research Methodology

In this paper, we will be exploring a solution to predict the defect in software using Support Vector Machine (SVM) with different kernel functions. The datasets that will be used are taken from NASA metrics Data Program, the number of features is 22 (4 McCabe metrics, 9 base Halstead measures, 8 derived Halstead measures and defect variable as output) as discussed before. Before using the Dataset, the Dataset will be pre-processed and cleaned by handling missing values and outliers. The datasets are divided to training and testing data. In Software Defect Predication (SDP) the selection of training data and testing data will be done in two different ways; the first one, in the same Dataset will be choosing the training and testing data randomly (or may be sequential). In second one, the training will be taking from Dataset as previous version and the testing data will be taking from another dataset as next version. We will use the first approach. The data will be handled and cleaned before running experiments. The proposed models will be validated using 10-cross validation. After that, the SVM with different kernel functions will be examined. The last step, the results will be compared and evaluated using classification accuracy measures such as: Recall, Precision, Classification Accuracy, and Balance. The tools that will be used are Rapid Miner for the implementation of our proposed solution. The accuracy of each model will be measured by the common accuracy measures: Recall, Precision, accuracy, Specificity, F-measure and Balance. Software Defect Prediction (SDP) detectors can be assessed according to confusion matrix or Error matrix: is a table used to describe the performance of classification model on a set of test data for which the true values are known. It is showed the number of correct and incorrect prediction, where is summarized with count values and broken down by each class. This is the key to the confusion matrix as shown in Table 3 Shepperd et al. (2014).

Table 3. Confusion Matrix

	Predicted as defective	Predicted as non-defective
defective	TP	FN
Non defective	FP	TN

Where TP is True positive which means correctly classified as defective module. TN is True negative which means correctly classified as non-defective module. FP is False positive which means classifies non-defective module as defective module, and FN is False negative which means classifies defective module as non-defective module.

To correctly identify a defective prediction, the "Precision" is used to determine the defective prediction rate, or the extent of the prediction is originally defective, or not. Recall is also called sensitivity, probability of detection (pd), or true positive rate (TPR). There are also many measures called probability of false alarm (pf) or false positive rate (FPR) which suggests the percentage of false defective predictions. Based on what has already, an optimal predictor should achieve TPR (pd) is 1, FPR (pf) is 0 and the Precision is 1. When the TPR and FPR are plotted, the result in Receiver Operating Characteristics (ROC) curve and from ROC the area under the curve (AUC) is to be measured. AUC is measured between 0 and 1, with 1 being the optimal solution point. Table 4 presents performance measures (Shepperd et al. (2014)). The, the data must be cleaned from missing value and outliers. The existing of missing values and outliers hinder the success of building accurate learning models therefore researchers suggested using some statistical tool to ignore these outliers such as boxplot. The missing values can be handled by either replacing them with the feature average of ignoring them. In this paper we ignore missing values because they are a few. The proposed algorithm must be validated using robust validation procedure such as cross validation and bootstrapping. During validation procedure the data is divided into training and testing subsets and training data is entered to learning the model while the testing data is used to evaluate accuracy of the model.

5. Experimental Results

This section presents the results of the experiment study, which has been conducted to validate our module. The evaluation has been performed on Support Vector Machine (SVM) with different Kernel functions, using public datasets obtained from PROMISE data repository as described in Dataset section. To evaluate

the performance of each proposed model, used 10-Folds cross-validation approach. This procedure divides the datasets randomly into 10-fold equal size subsets, where in each fold 9 subsets are used for training and one subset is used for testing. This process is repeated 10 times until all subsets act as testing data as described in section 3. In each experiment SVM model with different kernel function is constructed under two perspectives: using all features and using feature subset selected by PCA technique. Furthermore, six kernel functions were used: Linear, Quadratic, Cubic, Gaussian, RBF, Sigmoid.

Table 4. Performance measures

metric	Definition of the measure
Sensitivity	$\frac{TP}{TP+FN}$
Precision	$\frac{TP}{TP+FP}$
False positive rate	$\frac{FP}{FP+TN}$
Specificity	$\frac{TN}{TN+FP}$
Accuracy	$\frac{TN+TP}{TN+FN+TP+FP}$
Balanced Accuracy	$1-\frac{\sqrt{(0-pf)^2+(1-pd)^2}}{\sqrt{2}}$

5.1 CM1 Dataset Result

It can be noted from Table 5 that the Recall and Precision values are unacceptable for all kernel functions because their values are close to zero. Specificity values are very good for all kernel functions, with relatively similar values. Balance values are not very bad with a range between (0.29 - 0.4). Accuracy values are very good, as almost 90% of all kernel functions are good. TRP and FPR values are unacceptable for all kernel functions because they are nearly zero. "Area Under Curve" is acceptable for all kernel functions ranging from (0.50 - 0.64). With respect to all performance results, better solutions are observed for the Quadratic kernel function than the other five kernel functions with all features in the CM1 Dataset.

Table 5. Performance results of the SVM kernel functions on CM1 Datasets, using all Features.

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.00	0.00	1.00	0.29	0.90	0.00	0.00	0.62
Quadratic	0.16	0.42	0.98	0.41	0.90	0.16	0.02	0.64
Cubic	0.16	0.22	0.94	0.41	0.86	0.16	0.07	0.61
Gaussian	0.00	0.02	1.00	0.29	0.90	0.00	0.00	0.57
RBF	0.00	0.00	1.00	0.29	0.90	0.00	0.00	0.50
Sigmoid	0.08	0.29	0.98	0.35	0.89	0.08	0.00	0.53

Table 6. Performance results of SVM kernel functions on CM1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.00	0.00	1.00	0.29	0.90	0.00	0.00	0.44
Quadratic	0.18	0.41	0.97	0.42	0.89	0.18	0.03	0.71
Cubic	0.20	0.28	0.94	0.44	0.90	0.00	0.00	0.66
Gaussian	0.00	0.03	1.00	0.29	0.90	0.00	0.00	0.63
RBF	0.00	0.00	1.00	0.29	0.95	0.00	0.00	0.50
Sigmoid	0.10	0.19	0.95	0.36	0.87	0.10	0.05	0.53

It can be noted from Table 6 that the Recall and Precision values are unacceptable for all kernel functions; specificity values are very good for all kernel functions, with similar values. Balance values are not very bad with a range between (0.29 - 0.4). For all kernel functions with a range between (0.86 - 0.95) the accuracy values are so good. TRP and FPR values are unacceptable for all kernel functions, because they're almost zero. With all kernel functions with a range between (0.50 - 0.71) the values "Area Under Curve" are acceptable. With respect to all performance results, better solutions are observed for the Quadratic kernel function than the other five kernel functions considered with selected features in the CM1 Dataset. It was little improvement in all performance results when using selected features in CM1 Dataset. This is because of the features selected that were used.

5.2 KC1 Dataset Result

From Table 7 we can note that for all kernel functions the Recall values and Precision values are acceptable. Specificity values are generally good, as they are almost 96% for all kernel functions, with the exception for Sigmoid kernel that obtained of the 86%. Balance values with a range of (0.32 -0.55) are fairly good. The accuracy values for all kernel functions are relatively good with range between (0.78 - 0.84); TRP values are acceptable for all kernel functions except for the Cubic kernel function. FPR values for all kernel functions are unacceptable, as they are almost zero. "Area Under Curve" values for all kernel functions with a range between (0.66 - 0.81) are acceptable. With respect to all performance results, better solutions are observed for the RBF kernel function than the other five kernel functions considered with all features in the KC1 Dataset.

Table 7. Performance results of SVM kernel functions on KC1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.36	0.75	0.97	0.54	0.84	0.36	0.03	0.81
Quadratic	0.37	0.69	0.96	0.56	0.84	0.37	0.04	0.73
Cubic	0.37	0.54	0.97	0.55	0.81	0.37	0.08	0.67
Gaussian	0.37	0.74	0.97	0.56	0.85	0.37	0.03	0.77
RBF	0.36	0.70	0.96	0.54	0.84	0.36	0.04	0.66
Sigmoid	0.46	0.46	0.86	0.33	0.78	0.46	0.14	0.66

From Table 8 we can note that the values Recall and Precision are acceptable for all functions of the kernel. All kernel functions have very good specificity values, with a range between (0.85 - 0.97). Balance values with a range between (0.31 - 0.49) are acceptable. Accuracy values are so good for all kernel functions; as they are close to 84% except for RBF is 77%. For all kernel functions, TRP values are acceptable; FPR values are unacceptable, as for all kernel functions they are almost at zero. For all kernel functions with a range between (0.65 - 0.83) the values "Area Under Curve" are acceptable. With respect to all performance results, better solutions are observed for the Quadratic kernel function than the other five kernel functions considered with selected features in the KC1 Dataset.

When the selected features used in KC1 Dataset, all performance results were not improved except for Area Under Curve. This is because of the selected features that have been used, and we do not know how the mechanism of selection entities in cross-validation.

Table 8. Performance results of SVM kernel functions on KC1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.36	0.79	0.98	0.54	0.85	0.36	0.02	0.83
Quadratic	0.40	0.72	0.96	0.58	0.85	0.40	0.04	0.73
Cubic	0.43	0.62	0.93	0.59	0.83	0.43	0.07	0.65
Gaussian	0.36	0.68	0.96	0.55	0.84	0.36	0.04	0.69
RBF	0.35	0.66	0.95	0.54	0.83	0.35	0.05	0.65
Sigmoid	0.44	0.44	0.86	0.33	0.77	0.44	0.14	0.65

5.3 PC1 Dataset Result

From Table 9 it can be noted that the Recall values for all kernel functions are Totally unacceptable. Precision values for all kernel functions are acceptable, except the value for the Sigmoid kernel function. Specificity values for all kernel functions are very good as they are close to 96 %. Balance values with a range of (0.31- 0.49) are acceptable. Accuracy values are good for all functions of the kernel; since they are close to 91%. TRP values are unacceptable, as they are almost zero for all kernel functions with the exception of the Cubic kernel. FPR values are insufficient for all kernel functions, because they are almost zero. "Area Under Curve" values for all kernel functions with a range between (0.53 - 0.73) are acceptable. With respect to all performance results, better solutions are observed for the Cubic kernel function than the other five kernel functions considered with all features in the PC1 Dataset.

From Table 10 it can be noted that the Recall values for all kernel functions are totally unacceptable. Except for the Sigmoid and Cubic kernel functions, precise values are acceptable for all kernel functions. Specificity values are very good for all kernel functions; with the exception of Cubic kernel function, they are close to 97%. Balance values with a range of (0.31 - 0.49) acceptable. For all kernel functions, accuracy values are so good; with a range between (0.90 - 0.93) except for the Cubic kernel function, it is 77%. TRP

and FPR values are unacceptable, because they are almost zero for all functions of the kernel except for the Cubic kernel. "Area Under Curve" values for all kernel functions with a range between (0.51 - 0.75) are acceptable. With respect to all performance results, better solutions are observed for the Gaussian kernel function than the other five kernel functions considered with selected features in the PC1 Dataset. There was no improvement in all per-formance results except in accuracy when we used selected features in the PC1 Dataset. This is due to a function of the kernel, the selected features that were used and we don't know how the process of selection entities in cross-validation.

Table 9. Performance results of SVM kernel functions on PC1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.03	0.67	1.00	0.31	0.93	0.03	0.00	0.70
Quadratic	0.13	0.32	0.98	0.39	0.92	0.13	0.02	0.68
Cubic	0.29	0.39	0.97	0.49	0.92	0.29	0.03	0.67
Gaussian	0.08	0.55	1.00	0.35	0.93	0.08	0.01	0.73
RBF	0.08	0.67	1.00	0.35	0.93	0.08	0.00	0.54
Sigmoid	0.05	0.13	0.98	0.33	0.91	0.05	0.03	0.53

Table 10. Performance results of SVM kernel functions on KC1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.20	0.71	0.98	0.42	0.95	0.20	0.00	0.75
Quadratic	0.12	0.43	0.99	0.38	0.93	0.12	0.01	0.63
Cubic	0.40	0.10	0.83	0.50	0.75	0.48	0.22	0.55
Gaussian	0.10	0.67	1.00	0.35	0.93	0.13	0.00	0.69
RBF	0.08	0.72	1.00	0.37	0.93	0.11	0.00	0.53
Sigmoid	0.07	0.16	0.97	0.35	0.91	0.07	0.03	0.51

5.4 JM1 Dataset Result

It can be noted from Table 11 that the Recall values are unacceptable for all kernel functions except for the Cubic kernel function; it is 77%. Precision values are acceptable for all functions of the kernel except the functions Sigmoid and RBF kernel. Specificity values are very good, as they are similar to one% of Linear, Quadratic, and Gaussian kernel functions, becoming nearly 90 % of RBF kernel functions and unacceptable for Cubic and Sigmoid kernel functions. Balance values with a range of (0.21 - 0.36) are acceptable. For linear, quadratic, and Gaussian kernel functions, accuracy values are so good; as they are close to 81 percent, but unacceptable in the functions of Cubic, RBF, and Sigmoid. For all kernel functions except the Cubic kernel function, TRP and FPR values are unacceptable because they are nearly zero. "Area Under Curve" values are acceptable for all kernel functions with a range between (0.51 - 0.75). expect for cubic kernel function. With respect to all performance results, better solutions are observed for the Gaussian kernel function than the other five kernel functions with all features considered in the JM1 Dataset. It can be noted from Table 12 that the Recall values are unacceptable for all kernel functions except for the Cubic and Quadratic kernel functions, 40% and 61% are in order. Precision values are acceptable for all functions of the kernel, with the exception of Cubic and Quadratic functions. Specificity value is very good, as it is close to one for Linear, RBF, and Gaussian kernel functions, as it is close to 82% for Sigmoid kernel function and unacceptable for Cubic and Quadratic kernel functions. Balance values with a range of (0.29 - 0.49) are not that bad. Accuracy values are so good for linear, RBF kernel functions as they are nearly 81%. In Sigmoid kernel function is 77% unacceptable in Cubic, Quadratic, and Gaussian kernel function. TRP and FPR values are unacceptable for all kernel functions except for the Cubic and Quadratic kernel functions, as they are almost zero. "Area Under Curve" values are acceptable for all kernel functions with a range between (0.50 - 0.63) expect for Quadratic kernel function. With respect to all performance results, better solutions are observed for the RBF kernel function than the other five kernel functions considered with selected features in the JM1 Dataset. It was improvement when selected features used in JM1 Dataset, and no improvement in all performance. This is due to a function of the kernel, the selected features that were used and we don't know how the process of selection entities in cross-validation.

Table 11. Performance results of SVM kernel functions on JM1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.02	0.71	1.00	0.31	0.81	0.02	0.00	0.65
Quadratic	0.09	0.54	0.98	0.36	0.81	0.09	0.02	0.64
Cubic	0.76	0.19	0.21	0.21	0.32	0.76	0.79	0.48
Gaussian	0.10	0.61	0.99	0.37	0.81	0.10	0.02	0.62
RBF	0.01	0.34	0.90	0.30	0.18	0.01	0.10	0.55
Sigmoid	0.06	0.28	0.59	0.27	0.19	0.06	0.41	0.54

Table 12. Performance results of SVM kernel functions on JM1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.01	0.63	1.00	0.30	0.81	0.01	0.00	0.63
Quadratic	0.62	0.18	0.32	0.45	0.38	0.62	0.68	0.45
Cubic	0.41	0.20	0.60	0.49	0.56	0.41	0.40	0.50
Gaussian	0.09	0.60	0.96	0.35	0.58	0.09	0.04	0.59
RBF	0.08	0.58	0.99	0.35	0.81	0.08	0.01	0.53
Sigmoid	0.34	0.32	0.83	0.52	0.73	0.34	0.17	0.58

5.5 Class-Level Data for KC1 v1 Dataset Result

From Table 13, it can be noted that the Recall values are acceptable for all kernel functions except the RBF and sigmoid kernel functions as they are nearly zero. Precision values are acceptable for all kernel functions except the RBF and sigmoid kernel functions, as they are nearly to zero. Specificity values are very good, as they are near to one for RBF and Sigmoid kernel functions, other Kernels with rang between (0.66 -0 .83). Balance values are very good, as they are nearly to 77% except in RBF and Sigmoid kernel functions. Accuracy values are good as they are nearly to 77% in all kernel functions expect unacceptable in RBF, Sigmoid kernel functions. TRP values are good as they are nearly to 80% for all kernel functions except for the Sigmoid and RBF kernel functions. FBR values are unacceptable as they are nearly to zero for all kernel functions except for the Cubic, Linear and Quadratic kernel functions. "Area Under Curve" values are acceptable within the range between (0.50 - 0.84) for all kernel functions. For all performance results, better solutions are observed for the Gaussian kernel function than the other five considered kernel functions in the KC1version 1 dataset class-level data with all features.

Table 13. Performance results of SVM kernel functions on KC1 v1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.82	0.81	0.73	0.77	0.79	0.82	0.27	0.84
Quadratic	0.85	0.78	0.67	0.74	0.77	0.85	0.33	0.81
Cubic	0.79	0.77	0.67	0.72	0.74	0.79	0.33	0.79
Gaussian	0.75	0.87	0.83	0.79	0.79	0.75	0.02	0.83
RBF	0.00	0.00	1.00	0.00	0.43	0.00	0.00	0.50
Sigmoid	0.00	0.00	0.97	0.29	0.00	0.03	0.41	0.51

Table 14. Performance results of SVM kernel functions on KC1 v1 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.84	0.70	0.48	0.62	0.39	0.84	0.52	0.77
Quadratic	0.78	0.70	0.52	0.62	0.67	0.78	0.48	0.67
Cubic	0.71	0.71	0.58	0.64	0.66	0.71	0.42	0.65
Gaussian	0.90	0.69	0.40	0.57	0.70	0.90	0.60	0.08
RBF	0.70	0.65	0.73	0.71	0.72	0.70	0.27	0.71
Sigmoid	0.43	0.68	0.86	0.59	0.68	0.43	0.14	0.65

From Table 14, it can be noted that for all kernel functions the Recall values and Precision values are acceptable. For all kernel functions, specificity values are unacceptable, except for functions in the Sigmoid and RBF kernels. Balance values with a range of (0.57 - 0.71) are very good. Accuracy values are good for all kernel functions because they are nearly 66%. All kernel functions are good at the TRP and FBR values. "Area Under Curve" values are acceptable with a range of (0.65 - 0.80) for all kernel functions. For all performance results, better solutions are observed for the Gaussian kernel function than the other five considered kernel functions in the KC1version 1 dataset class-level data with selected features. Dataset used in class-level data were improved in Recall, Precision, Balance, TPR and FPR, there was no improvement in Area Under Curve and another performance was getting bad including Specificity and Accuracy. It is due to a function of the kernel, the selected features that were used and we don't know how the mechanism of selection entities in cross-validation.

5.6 Class-Level Data for KC1 version 2 Dataset Result

From Table 15, it can be noted that for all kernel functions, the Recall values are nearly 100%, except for the sigmoid and RBF kernel functions, as they are close to zero. Precision values are so good because the majority values are close to 95% in order for all kernel functions except RBF and sigmoid kernel functions. Specificity values are unacceptable because for all kernel functions, they are close to zero except for the Sigmoid and RBF kernels; they are 100% and 87% in order. Balance values with a range between (0.29-0.38) are not that bad, except for functions in the RBF and Sigmoid kernel, because they are nearly zero. The accuracy values are so good that they are near to 94 percent for all kernel functions except RBF, that it's nearly zero. TRP and FPR values are as good as similar to one for all kernel functions with the exception of the RBF and Sigmoid kernel functions, as they are nearly zero. "Area Under Curve" values are acceptable with a range between (0.50 - 0.74) Cubic, Sigmoid, and RBF kernel function, and other kernels are near to one. With respect to all performance results, better solutions are observed for the Gaussian kernel function than the other five kernel functions considered in the KC1version 2 dataset class-level data with all features.

From Table 16, it can be noted that the Recall values are nearly to one for all kernel functions except the sigmoid and RBF kernel functions, as they are near to zero. Precision values are so good that for all kernel functions, except for RBF and sigmoid kernel functions, they are close to 97%,

because they are nearly zero. Specificity values are unacceptable because they are nearly zero for all kernel functions, except for the Sigmoid and RBF kernels, as they are near to one, and in the Cubic kernel function, they are 50%. With a range of (0.29-0.47), balance values are acceptable except for Cubic and Quadratic kernel functions, as they are close to 64 %. TRP values are as good as near to one for all kernel functions except for the RBF and Sigmoid kernel functions as near to zero%. With the exception of the RBF and Sigmoid kernel functions, FPR values are so good with a range of (0.50 - 1.0) because they are close to zero %. "Area Under Curve" values are acceptable for the feature of the Sigmoid and RBF kernels, as they are nearly 50% other kernels, they are almost 85%. For all performance results, better solutions are ob-served for the Gaussian kernel function than the other five kernel functions considered in the KC1version 2 dataset class-level data with all features.

The comparison of the proposed classifier with the Support Vector Machine (SVM) with different kernel functions applied for the same NASA datasets in terms of the performance metrics: sensitivity, specificity, probability of false alarm, balance, accuracy, and area under the curve. The results were different within the Dataset because each Dataset has a different number of entities, some data have 125 such as KC1version 2 class-level data, other datasets have 10,000 entities and this affects the cross-validation selection process. For some datasets the selected features perform better in the same Dataset and in other datasets there is no improvement at all.

Table 15. Performance results of SVM kernel functions on KC1 v2 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.99	0.95	0.13	0.38	0.95	0.99	0.88	0.93
Quadratic	0.99	0.95	0.13	0.38	0.95	0.99	0.88	0.92
Cubic	0.97	0.95	0.13	0.38	0.92	0.97	0.88	0.74
Gaussian	1.00	0.95	0.00	0.00	0.95	1.00	1.00	0.89
RBF	0.00	0.00	1.00	0.29	0.95	0.00	0.00	0.50
Sigmoid	0.01	0.50	0.88	0.08	0.06	0.01	0.13	0.51

Table 16. Performance results of SVM kernel functions on KC1 v2 Datasets, using PCA

Kernel	Recall	Precision	Specificity	Balance	Accuracy	TPR	FPR	AUC
Linear	0.99	0.96	0.25	0.47	0.95	0.99	0.75	0.81
Quadratic	0.99	0.97	0.50	0.65	0.96	0.99	0.50	0.85
Cubic	0.99	0.97	0.38	0.64	0.96	0.99	0.63	0.83
Gaussian	1.00	0.95	0.00	0.29	0.95	1.00	1.00	0.83
RBF	0.00	0.00	1.00	0.29	0.95	0.00	0.00	0.50
Sigmoid	0.00	0.00	0.99	0.29	0.94	0.00	0.01	0.50

6. Conclusion

Software Defect Prediction is a vital task during software development to help testing team to focus on defect proneness modules. To support that, various machine learning methods have been used to build models that can predict faulty modules based on datasets collected from software industries. Among them, Support vector machine has shown good performance for this problem, but there are no prior studies examined the performance of kernel functions for defect prediction problem. Thus, this research we will examine the performance of support vector machine with different kernel functions over different datasets collected from software data repositories. The results demonstrate that there is no kernel function that can give stable performance across different experimental settings. In addition, the use of feature subset selection using PCA did improve accuracy of kernel functions over some datasets. In CM1 Dataset, better solutions are observed for the Quadratic kernel function than the other five kernel functions with all and selection features. In KC1 Dataset, better solutions are observed for the RBF kernel function than the other five kernel functions with all and selection features. In PC1 Dataset, better solutions are observed for the Cubic kernel function than the other five kernel functions considered with all features, but when select some features, the better solutions are observed for the Gaussian kernel function than the other five kernel functions. In JM1 Dataset, better solutions are observed for the Gaussian kernel function than the other five kernel functions with all features, but when select some features, better solutions are observed for the RBF kernel function than the other five kernel functions. In Class-level data for KC1version 1 dataset, better solutions are observed for the Gaussian kernel function than the other five considered kernel functions in all and selected features. In in the KC1version 2 dataset class-level Dataset better solutions are observed for the Gaussian kernel function than the other five kernel functions considered with all and selected features. The results were different within the Dataset because each Dataset has a different number of entities, some data have 125 such as KC1version 2 class-level data, other datasets have 10,000 entities and this affects the cross-validation selection process. For some datasets the selected features perform better in the same Dataset and in other datasets there is no improvement at all.

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Towards the development of a recommender system for product delivery using graph databases and related algorithms

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Abstract

Recommendation systems are among the promising strands of machine learning that have revolutionized information retrieval operations. These systems are designed to make recommendations to users based on different factors.

The realization of a recommender system requires a study of the users' needs and the metrics that may influence each recommendation, as well as the attributes that can be entered into the application but that have no effect on the system's functioning.

In this context, SoftCentre[1] aims to develop a delivery recommender system using graph databases and related algorithms, in order to figure out the best path for each delivery to its destination. In this context, the deliverer will respect deadlines, specifications, and deduce the best itinerary to travel on.

Therefore, our project revolves around the design, modeling, and implementation of a recommendation system based on these main phases: 1)Data collection and preprocessing, 2)Graph database creation, and 3)Applying recommendation and optimization algorithms.

Keywords: Recommendation system, process model, Hybrid filtering, Graph database, Neo4j, Cypher, Python

[1] organization that creates national champions in the software industry to improve Morocco's international attractiveness

1. Introduction

There are many mobile (Jumia, Food on Demand, Glovo, etc.) or desktop applications (El Morocco Club, Best Restaurants, etc.) that present a wide choice of restaurants, menus, meals, and best places to visit, as well as suggest delivery services according to the customer's profile, his budget, his preferences, and his current geographical location. However, as a deliveryman, there is no system that considers orders' preferences and availability, especially for independent delivery people who have to do auto-orders. This random process makes the deliverer lose time in navigating and selecting deliveries, as well as allows him to make an unfavorable selection with incompatible orders and deliver a minimum number of orders across a very long route.

Thus, the current method has several limitations: deliverers suffer during the search from information overload due to published orders, publications on several sites, waste of time, lack of user experience personalization, and are shocked by the fact that the amount of information they are confronted with is greater than their capacity to process it. Moreover, they always wait for a user's request to recommend references. Indeed, there is a lack of informational data from deliverers and customers' requests. In this sense, general information provides a lack of adaptation to the user's interest in recommending and valuing contents such as deliverer metadata, customer metadata, descriptive information about orders, new deliveries, and funds that have historical value.

From a technical point of view, a delivery referral system is effective when it meets the needs of functional requirements. The system must take into consideration the delivery customer's evaluation and build a user model from the collected data, relying on real-time data (current geographic location). Also, it is required to take into consideration non-functional requirements.

The evaluation result aims to improve the performance and quality of the functional requirements of the recommended system. This is done by personalizing recommendations according to the deliverer profile and availability of customer point of view as recommendations for any deliverer connected to the application. In this sense, the deliverer has to respect deadlines, specifications, and deduce the right itineraries. Therefore, the deliverer has to respect the deadlines and specifications of each command and order and propose the optimal delivery route. In this context, we aim to create a recommender system that will work as background of a mobile application. Thus, the focus of this system is to provide real-time recommendations to each deliverer, about the best route path between two specific destinations, based on their geographical location, vehicle type, capacity, and availability, in order to reduce the total distance that will be travelled/forwarded (the total cost). In addition, it is rentable in terms of increasing the density of routes, the size of the delivery points by grouping deliveries according to location, proximity, delivery schedule, and order specifications.

To resolve this problem, the key technology for enabling real-time recommendations is the graph database (Kamphuis, 2020), a technology that is quickly leaving traditional relational databases behind. Graph databases easily outperform relational and other NoSQL databases in connecting masses of user and product data (connected data in general) to better understand customer needs and product trends. The biggest advantage of using a graph data model is that there is no need to connect entities within the data using special properties such as foreign keys. In a graph database, it becomes very easy to understand relationships between entities because the data structure is

well organized and very noticeable.

In this paper, we use Neo4j (Zhu et al., 2019), which is a graph database management system that also provides tools to visualize and extract important information from the graph database. This is done based on the Neo4j's graphical query language that allows users to store and retrieve data from the graphical database (Cypher).

Cypher (Francis et al., 2018) is not only the best way to interact with data and Neo4j. Cypher's syntax provides a visual and logical way to match patterns of nodes and relationships in the graph, which allows users to build expressive and efficient queries to handle the necessary creation, reading, updating, and deleting functionality. Indeed, SoftCentre[2] aims to develop a delivery recommender system using graph databases in order to optimize routes for each delivery to its destination.

The reminder of this paper is organized as follows: The second section presents a literature background on existing recommender systems, techniques, and algorithms. The third section presents our recommended system architecture with an illustrative example of its application. The fourth section summarizes the paper and introduces future work.

2. Related Work

We will devote this section to presenting how the literature defines some key concepts and notions related to our study. Thus, we will present how existing recommendation systems operate.

[2] organization that creates national champions in the software industry to improve Morocco's international attractiveness

2.1 Techniques for recommendation

Recommendation or recommender systems (Karimi et al., 2018) are algorithms that suggest relevant elements (movies to watch, texts to read, products to buy or any other element depending on the sector of activity) to users.

All recommendation algorithms are based on the following concepts:

These algorithms aim to find entities with similar properties and calculate their "similarity" measure (Prasetya et al., 2018). For example, customers who live in the same area, have the same age, or share common interests can be "grouped". This requires the analysis of customer choices. Indeed, it is possible to propose suitable recommendations by taking into consideration the executed activities of two similar clients. These two steps of the recommendation process depend on logical links between customers and between customers and their purchases. Therefore, the faster we can query and traverse these links, the stronger our ability to provide real-time recommendations is. In this context, there are many techniques used to make a recommendation system, which are illustrated in the diagram of Figure 1.

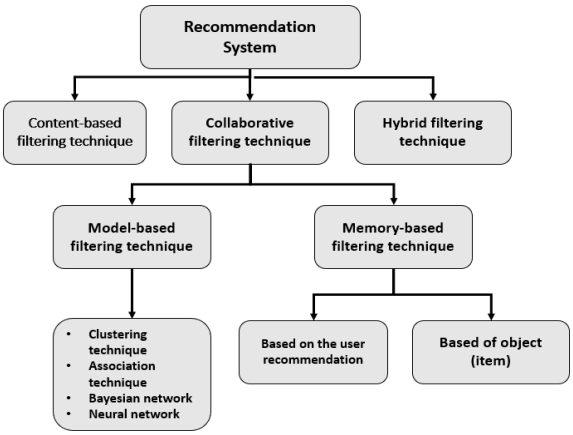

Fig. 1. A summary of existing approaches to recommendation systems

a. Content-based filtering technique

The content-based filtering technique (Bharti and Gupta, 2019) is used to analyze a set of items that have been evaluated previously by users in order to generate a prediction based on their evaluation.

To generate a complete sense of recommendation, different types of models will be used to find the similarity between documents, such as vector space models, probabilistic models, and neural networks. With this technique, we do not need a user profile, as it has been done using machine learning or statistical analysis.

The advantages of this technique are as follows: a) it provides privacy, b) there is no need to share the user's profile, c) recommendations are made in a short period of time, and it can recommend new items even if there is no rate on them.

On the other hand, it has disadvantages, namely: a) content-based filtering depends on the metadata of the item, and b) it is limited and requires a detailed description of the items.

b. Collaborative filtering technique

This technique (Nilashi et al., 2018) cannot be described easily using metadata because it is a domain-independent prediction technique. This technique is used to build a database between a user and an article as a performance table for articles written by users. Then it is required to calculate similarity by matching users with relevant articles.

The item recommended to the user depends on how similar users rate this article. In addition, this technique has two types: 1) model-based filtering techniques, which depends on clustering, association, Bayesian network, and neural network techniques; and 2) memory-based filtering technique like user-based and item-based techniques. It also has some advantages, such as the need for user evaluation to find similarity between them for establishing recommendations; it displays the recommendation items that an unknown user likes or evaluates; a new item can be suggested even if it has not been evaluated. On the other hand, this method has a disadvantage for new users, where recommendations will not be provided correctly, and items will not be recommended if there is no information to discriminate against.

c. Hybrid filtering technique

This technique (Parsian et al., 2017) is performed by combining several techniques to avoid the systems' limitations. Therefore, the result will be more accurate than a single algorithm. Each technique has weaknesses which can be overcome by combining them with another technique.

There are different ways to match this combination, such as implementing algorithms separately and then combining the results. Thus, we can use the content-based filtering technique (Bharti and Gupta, 2019) in the collaborative filtering approach and the collaborative filtering technique (Nilashi et al., 2018) in the content-based filtering approach.

2.2 Social media Recommendation systems

Currently, several recommendation systems are based on graph databases. 1) hybrid video recommendation system based on a graph-based algorithm (Öztürk, 2010); 2) book recommendation using Neo4j Graph Database in BibTeX Book Metadata (Dharmawan and Sarno, 2017); and 3) the Impact of the YouTube Recommendation System on Video Views (Zhou et al., 2010).

Firstly, the hybrid video recommendation system

(Öztürk, 2010) is based on a graph algorithm using a graphical algorithm called Adsorption. Adsorption (Raj et al., 2020) is a collaborative filtering algorithm in which logical links between users are used to make recommendations. Adsorption is used to generate the basic recommendation list. To overcome problems that have occurred in a collaborative system, content-based filtering is injected. Content-based filtering uses the idea of suggesting similar items that match the user's preferences, and the recommendation list is updated by removing weak recommendations. Then, similarities between items in the remaining list are calculated, and new items are inserted to form the final recommendation. Thus, recommendations are strengthened by considering the similarity algorithm between items. Therefore, the developed hybrid system combines both the collaborative approach and the content-based approach, to produce more effective suggestions.

Secondly, book recommendations Using Neo4j Graph Database in BibTeX Book Metadata (Dharmawan and Sarno, 2017) consists of processing the book metadata so information can be displayed to the user who needs a book recommendation. By combining BibTeX book metadata with Neo4j's graphical database, the data and metadata can be processed. Then, with an encrypted query, by entering the author or book type parameter, the user can get book recommendations based on their input criteria.

The result is exactly the same as with manual processing of metadata in the relational database. According to this article, it takes 180 milliseconds to run a cypher query with author criteria, and 184 milliseconds to run a query with book type criteria.

Last, the YouTube Recommendation System on Video Views (Zhou et al., 2010) presents a measurement study on datasets from YouTube. We find that related video recommendation, which recommend videos that are related to the video a user is currently watching, are one of the most important sources of video views. Despite the fact that YouTube video search is the top source of viewing in aggregation, related video recommendations is the top source of views for the majority of videos on YouTube (Lopezosa et al., 2020).

Furthermore, results reveal that there is a strong correlation between the number of views a video has and the average number of views of its most recommended videos. This implies that a video is more likely to become popular when it is placed on popular video recommendation lists. We also find that the click-through rate from a video to its related videos is high, and that the position of a video in a list of related videos plays a key role in the click-through rate. Indeed, the evaluation of the impact of the related video recommendation system on the diversity of video views indicates that the current recommendation system increases the diversity of video views in the aggregation.

3. Our Proposed Delivery Recommender system

In this section, we will detail our recommended system architecture, as well as the steps to follow in realizing it.

Our recommender system uses both collaborative filtering techniques and content-based recommendation (a hybrid recommender system). The collaborative part is where a set of algorithms will be used. The content-based technique is used to make recommendations in a short period of time, and it can recommend new items even if there is no rate on them. Therefore, our recommender system will be used to recommend the optimal path for a deliverer to achieve its order destination.

3.1 Framework

a. Overview

The system involves several actors, either directly or indirectly. These different actors are:

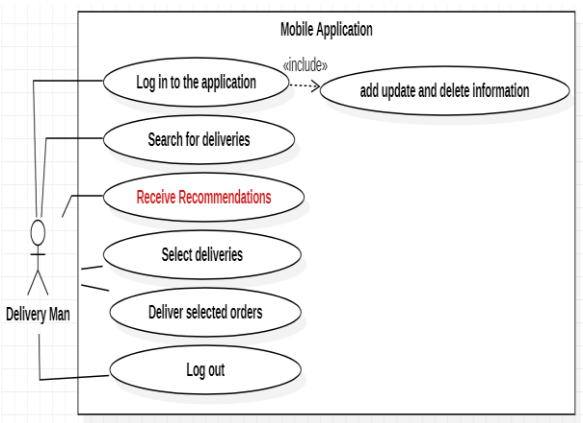

Fig. 2. Use Case

The administrator intervenes in an indirect way, by managing the system and by having the right to act through numerous actions, defined as follows: Log in and log out; Adding a user or an order (command), updating the system information, or deleting specific information. The user (the deliverer or delivery man): this is the main actor in the system. He interacts through the following actions: logging in, accessing his account, or logging out; He can update his profile information, search and view search results, as well as receive delivery recommendations based on his profile.

The diagram in Figure 2 models the use case of the mobile application combined with our recommended system for visualizing results.

b. Exemplar scenario

Figure 3 presents a scenario that is defined by a departure point and an arrival point. Throughout this scenario, participants react to the system through several actions. First, the driver must connect to the application according to his detected geographical position and the keywords of the search he makes. Afterwards, the system can propose deliveries that are in turn defined by numerous metrics, namely the size, the weight, the geographical points of pickup and destination, as well as the type of logical links between the deliverer and the customer. This is based on the rating that the deliverer gives to the customer. These static and dynamic parameters (in real time) are the core of our system, which affects the results of the recommendation (Figure 3 shows this recommendation process).

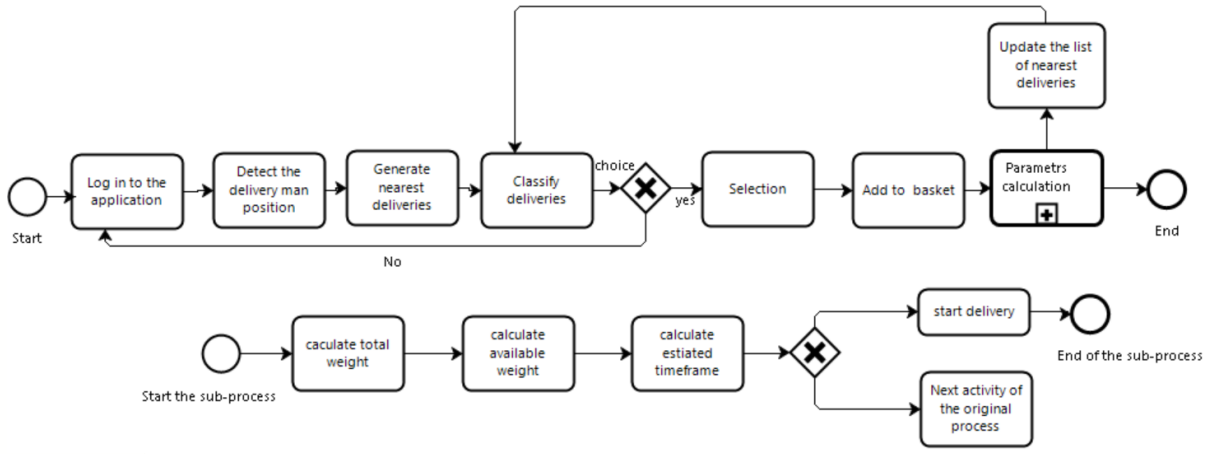

Fig. 3. Full Recommendation scenario with the parameters' calculation sub-process

3.2 Data collection

Our system is part of a project that develops a mobile application dedicated to independent delivery drivers. The delivery requests are published on the application and can be defined by data and metadata, which belong to the description of each request. This data is generated by the mobile application, and it will be considered the input data (output) of our system, on which the recommendation algorithms of our solution are based.

```
Commandes.head()
```

	IdCommande	Contenu	Catégorie	Nature	Taille	Date_de_livraison	Heure de Livraison	Org_lat	Org_lon	Des_lat	Dest_lon	ClientID
0	MVCV00000270	sandwitch, soda	Produits alimentaires	Fragile	Petite	2020-08-17	14:59:00	11.877200	7.063020e+01	12.7124	77.8125	ALLEXCHE450
1	VCV000142711	chat	Animeaux domestiques	Lourd	Moyenne	2020-08-27	16:21:00	12.786517	7.697522e+01	12.8319	79.9514	DMREXCHEUX1
2	VCV000143822	four	Electromenager	Léger	Petite	2020-08-27	17:57:00	30.000500	7.673221e+07	11.8711	79.7339	LUTGCCHE062
3	VCV000147433	vetements	Autres	Fragile	Grande	2020-08-28	00:42:00	13.087428	1.319509e+01	12.8239	79.9524	DMREXCHEUX3
4	VCV000147444	vélo	Autres	Lourd	Moyenne	2020-08-28	01:13:00	11.711540	7.781325e+01	11.8372	79.6322	LUTGCCHE064

```
Livreurs.head()
```

	IdLivreur	Curr_lat	Curr_lon	VéhiculeId	Disponibility	Mobility
0	VIJEXHOSR7	12.663500	78.649870	73fc7af87114b39712e6da79b0a377eb	1	I
1	VJLEXSHE09	12.836757	79.954428	a548910a1c6147796b98fdf73dbeba33	1	O
2	GSTEXLAK1Q	13.073956	80.225780	f9e4b658b201a9f2ecdecbb34bed034b	0	O
3	ARVEXNAM09	12.846686	79.950560	658677c97b385a9be170737859d3511b	1	I
4	SRTEXKOR96	12.429501	79.831556	8e6bfb81e283fa7e4f11123a3fb894f1	0	O

```
Clients.head()
```

	ClientID	Client_lat	Client_lon	Genre	Age	Note
0	ALLEXCHE450	12.7124	77.8125	Female	42	3.75
1	DMREXCHEUX1	12.8319	79.9514	Male	20	1.00
2	LUTGCCHE062	11.8711	79.7339	Male	40	2.25
3	DMREXCHEUX3	12.8239	79.9524	Male	70	2.75
4	LUTGCCHE064	11.8372	79.6322	Male	56	3.75

```
Vehicules.head()
```

	VéhiculeId	VehiculeType	VehiculeCapacity	IdLivreur
0	73fc7af87114b39712e6da79b0a377eb	Moto	20	VIJEXHOSR7
1	a548910a1c6147796b98fdf73dbeba33	Triporteur	125	VJLEXSHE09
2	f9e4b658b201a9f2ecdecbb34bed034b	Camion	27000	GSTEXLAK1Q
3	658677c97b385a9be170737859d3511b	Camionnette	1200	ARVEXNAM09
4	8e6bfb81e283fa7e4f11123a3fb894f1	Voiture	300	SRTEXKOR96

Fig. 4. Generated database (tables: orders, deliverers, customers, and vehicles)

In our case, the project is under development, which means that there is no data to be generated. Therefore, the production of false (true) data is required for the realization of the first step of our solution. To that end, there are many existing databases on the web that contain data that is compatible with our solution. Kaggle[3] is one of the platforms with rich and varied content in the field of data science, and on which there are different types of delivery request da-

[3] https://www.kaggle.com

tabases to generate useful data from this platform.

With the help of the Python packages, we can easily resolve several problems with simple code. In this step, we relied on the following two packages, Beautifulsoup and Faker, to generate the rest of the data, because we were not able to pull this data according to the first scenario.

There are numerous platforms to generate data, such as Mockaroo[2]. Mockaroo is a website that we have used to generate realistic but entirely fake data. It allows generating a wide variety of fake data from many domains and with high volumes. Also, it can be used to simulate the beta version of our API until the real APIs are completed. All these methods are explored for the data generation of a database that is made up of 4 tables in CSV format (see Figure 4). The first table contains information about orders (French: commandes), the second table depicts information about deliverers (French: livreurs), the third table contains information about customers (French: clients), and the fourth table contains information about vehicles (French: véhicules).

3.3 Data preparation

After database creation with specific metrics, we will process these metrics to yield logical results by removing noise.

Data preprocessing is a data mining technique that involves transforming raw data into an understandable format. Real-world data is often incomplete, inconsistent, and/or lacking in certain behaviors or trends, and is prone to many errors. Data preprocessing is a proven method to solve these problems. To this end, we have based ourselves on four steps: data cleaning, data integration, data reduction, and data transformation (see Figure 6). For instance, the database contains several missing values (see Figure 5). This data can negatively influence the learning results. To solve this problem, we have to re-encode some of those missing values. To do this, we have used imputation, which means replacing the missing value with any number. In most cases, the imputed value will not be exactly accurate, but it usually gives more accurate models than dropping the column completely.

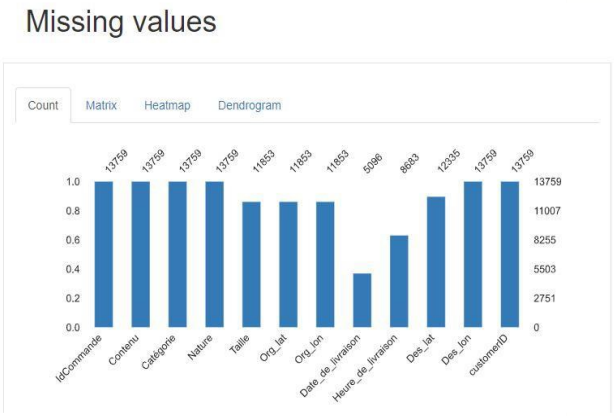

Fig. 5. Exploring missing values

3.4 Graph database

After processing the database and exporting it into new CSV files, we proceed to create the graph database, on which we will apply all the algorithms of the recommendation process. Then, we derive a graph model from a relational model, and we have to apply the following guidelines: a row is a node; a table name is a label name; and a join or foreign key is a logical link.

a. Nodes' creation

To create the nodes of our graph database, we begin by importing CSV files that contain the tables of the relational database. The output of each script gives the number of nodes created from the CSV file, the number of properties, and the execution time. e.g., 13759 order nodes, 6521 customer nodes, and 6880 deliverer nodes (see Figure 6).

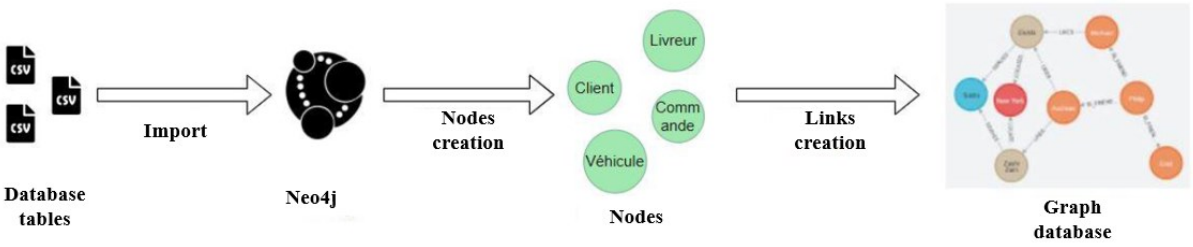

Fig. 6. The process of creating a graph database

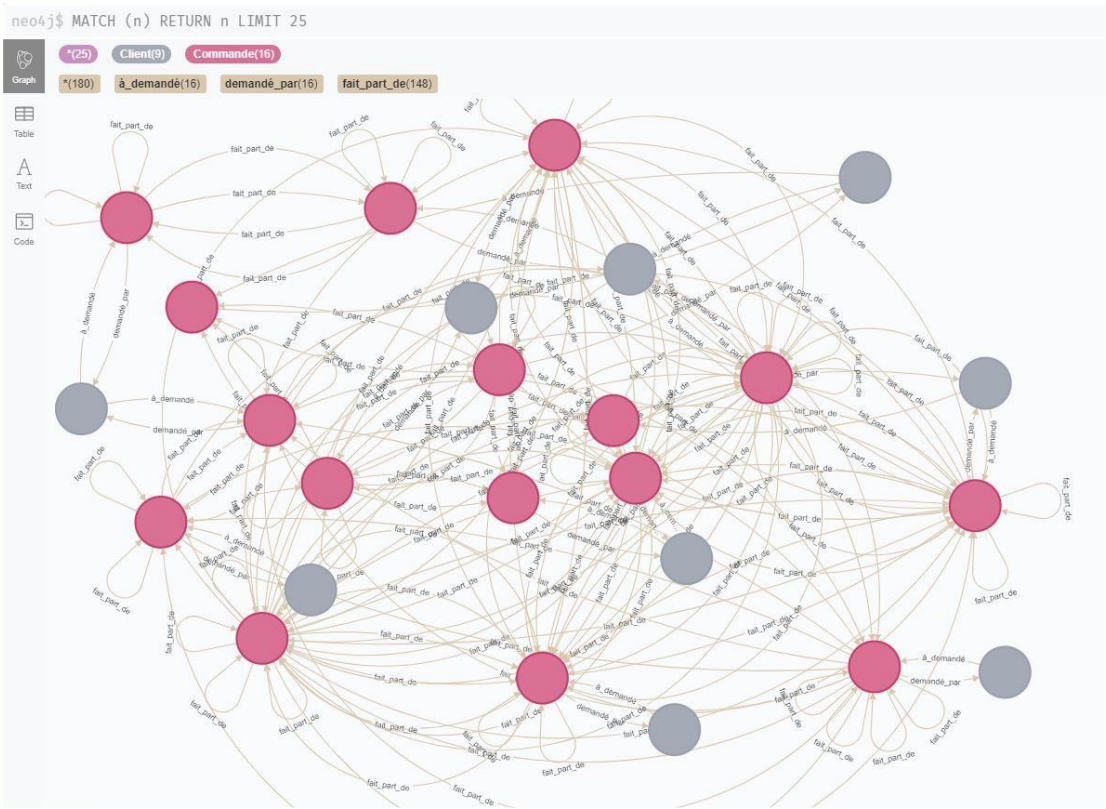

Fig. 7. Our graph database

b. Logical links and constraints creation

At this stage, we will create logical links between different nodes to obtain the graph of our database. To do this, we need to start by creating the indexes and the constraints on the properties that will be the links between the nodes. To successfully create the relationships, a constraint must be placed on the order identifier, which must be unique.

The goal of our study is to recommend a set of deliveries to a deliveryman, so the first relations are, on the one hand, those that link the orders with the customers, and on the other hand, those between the deliverers and the vehicles.

The graphical representation of the database (see Figure 7), based on the connections between the nodes, is faster when dealing with large amounts of data, so it is more efficient in the sense of searching for recommendations based on the relationships that link the different entities in the database.

3.5 Implementation

After creating the graph database, it is time to manipulate its data using the algorithms of the Neo4j Graph Data Science library (Needham and Hodler, 2019) as shown in Figure 8.

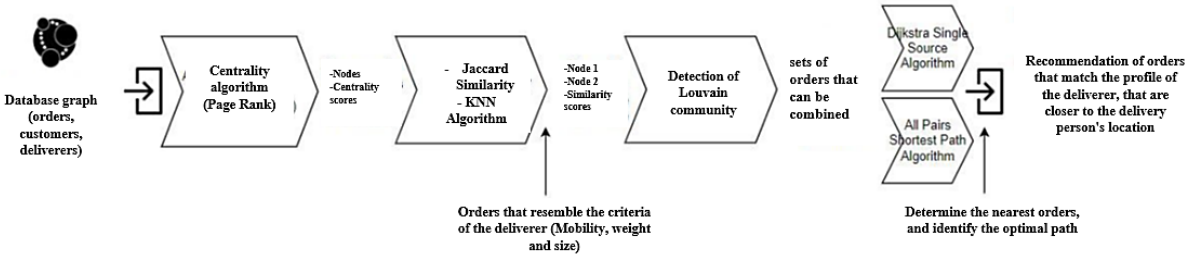

Fig. 8. The process of applying recommendation algorithms to the graph database

a. PageRank and Similarity Algorithm

The first step is to calculate the centrality of the order nodes using the PageRank algorithm (Xing and Ali, 2005). This algorithm calculates a score for each node and then displays them in order. This allows us to have the most important nodes in the graph that influence the rest of the algorithms. Then, we will calculate the similarity between a node of a given supplier and the properties of the orders using the node similarity algorithm based on Jaccard Similarity (Niwattanakul et al., 2013).

The configuration of this similarity considers the mobility and availability properties of the deliverer along with the mobility of the order. These algorithms allow the filtering of orders that do not match the profile of the deliverer, which will not be counted in the selection of recommendations.

b. Route Path optimization

To recommend an action based on route optimization, we need to select the orders closest to the location of the deliverer. The path taken by the delivery will be as shown in Figure 9. In order to optimize this path, we need to calculate the distance between the current position of the origin of the order as well as the distance between the starting point of the order and the order's point of departure and the point of arrival. To do this, we will use the Neo4j spatial library (Ashokkumar Arunkumar, et al. 2018).

First, we need to convert the geographic (see Figure 9) coordinates and create a point defined by the latitude and longitude. These parameters are used to calculate the distance between two geographical points, which are the origin of the order and its destination. The same calculation is applied to the distance between the delivery and the origin of the order.

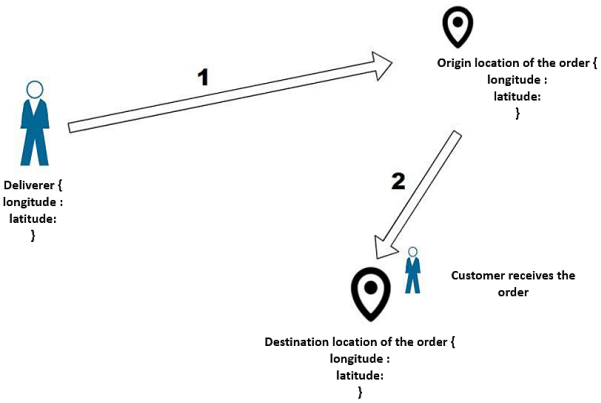

Fig. 9. Deliverer route

After calculating the distances, we can apply the shortest path algorithm (Gómez et al., 2019) to optimize the route path (ALL Pairs Shortest Path Algorithm). The result is illustrated as a ranking of the shortest paths between a pair of nodes using the total distance values between these aforementioned nodes. Figure 10 shows the result obtained by applying the shortest path algorithm to our database.

To define the closest orders to a given deliverer, we used the Dijkstra Single algorithm (Permana et al., 2018). This algorithm calculates the shortest paths between a source node, which is the delivery node in this case, and all the nodes reachable from this node, which are the orders. The application of this algorithm requires the use of a fixed starting node, so that the result can be represented as the distance between this node and all other nodes.

After selecting the closest orders to the delivery driver, we create a new group based on the nature and content of each order. At this point, the delivery driver can make multiple deliveries. To do that, we have used the community detection algorithm, the LOUVAIN algorithm (Zhang et al., 2021). This algorithm is used to nominate groups that can classify general orders and orders that belong to a specific group. The main idea consists of using these groups to provide the set of recommendations that will be displayed to the deliverer (see Figure 11).

①

②

```
CALL gds.nodeSimilarity.stream('pfeGraph')
YIELD node1, node2, similarity
RETURN gds.util.asNode(node1).name AS Commande, gds.util.asNode(node2).name AS Livreur, similarity
ORDER BY similarity DESCENDING, Commande, Livreur
```

③

```
LOAD CSV WITH HEADERS FROM "file:///Commande.csv" AS row
CREATE ( n : OrgLoc) SET n=row,
n.longitude =toFloat(row.Org_lon),
n.latitude =toFloat(row.Org_lat)

CALL spatial.geocodeOnce('geom_noeuds',{OrgLoc , DesLoc},0.1) YIELD location
WITH location, distance(OrgLoc,DesLoc) AS distance
RETURN OrgLoc.name, DesLoc.name, distance
ORDER BY distance
```

Fig. 10. Recommendation algorithms' application (Page rank ①, Similarity ②, Distance ③)

Fig. 11. Optimization algorithms' application (Shortest Paths ①, Dijkstra ② and Louvain③)

4. Conclusion

In this paper, a hybrid recommender system is presented. The system uses both collaborative filtering and content-based recommendation techniques. In this context, we use a set of recommendation and optimization algorithms. Therefore, our project revolves around the design, modeling, and implementation of a recommendation system based on the active filtering of orders published in the discussed mobile application.

To that end, we collected a large volume of data to create our relational database. Then, we converted the resultant database to a graph database using Neo4j libraries. Also, we applied a set of algorithms dedicated to data manipulation, which allowed us to generate recommendations for a given deliverer using Cypher and Python libraries. Furthermore, this helps the system personalize orders, contents, and deliveries by exploiting connections between data -all in real time- and matching deliverers with orders based on their profiles, preferences, and past online activities. In this context, we opt for a hybrid filtering approach that combines several algorithms and techniques. Therefore, the result is more accurate than a single algorithm.

In further work, it is important to treat the ability of process mining techniques to model uncertain behaviors of self-defined processes related to information retrieval systems. This is in line with the objective of achieving business process maturity and measuring how effectively and efficiently the self-defined BP is working.

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On the Marketing Strategy of Barreled Liquid Fuel

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Abstract

Although experts' prediction that the global oil will be consumed in 50 years is not so sure, the massive consumption of oil is forcing the search for new clean, effective, but high-cost energy sources. One of these is the liquid fuel produced in the process of refining petroleum. Aiming at Taiwan's heavy dependence on gas barrels, this research proposes a new liquid gas replacement for liquid fuel. The fuel is liquid at room temperature and is installed in a particular PE plastic barrel. When in use, it is converted into gas through aeration and then ignited and burned for use. This product has almost exactly the same burning cost as liquid gas, and its higher flame temperature reduces the cooking time by 25%. Moreover, it can be self-filled with liquid fuel. The pressure in the barrel is low, and there is no safety concern about gas explosion. The technology has been patented. However, due to Taiwan's current habit of using liquid gas, this product faces a marketing dilemma and cannot find an opening in the domestic market. This research intends to adopt a disruptive innovation marketing strategy to solve the dilemma. For a market (such as Hong Kong) that needs the advantages of this product but ignores the shortcomings, a functional analysis is conducted and identifies seven provocative questions, including contradictory problems. Then, we use brainstorming and the TRIZ 40 inventive principles recommended by CREXA to develop 13 marketing strategies, and use 4P to classify them.

Keywords: Disruptive innovation, 4P, aeration, 40 inventive principles, marketing strategy.

桶裝液態燃料的行銷策略探討

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摘要

雖然專家預測全球的石油將於 50 年消耗完畢並不是那麼確定，石油的大量消耗迫使新的乾淨、有效但是高成本的能源勢必需要被尋找出來。其中一種就是提煉石油的過程中所產生的液態燃料。本研究針對台灣對瓦斯桶的嚴重依賴，提出一種新的液態燃料-取代液態瓦斯。該燃料在常溫下呈液態，裝置在特殊的 PE 塑膠桶子內，在使用時經過曝氣作用轉為氣體然後點火燃燒使用。本產品與液態瓦斯的燃燒成本相同、其較高的火焰溫度使得烹煮時間減少 25%、可以自我填充液態燃料，桶內壓力低不會有氣爆的安全顧慮，並且技術已被專利保護。然而，由於目前人們使用液態瓦斯的習慣，造成此產品面臨行銷困境，無法在台灣市場打開。本研究擬採用突破式創新的行銷策略，往需要本產品的優勢卻忽略本產品的缺點的市場行銷(例如香港特別行政區)進行功能分析發想 7 個刺激性問題，其中包含矛盾問題。接著用腦力激盪及 CREXA 所建議的萃智 40 發明原則想出 13 項行銷策略，並用 4P 分類。

關鍵詞： 突破式創新，4P，曝氣，40 發明原則，行銷策略。

1. 前言

由於工業和運輸的大量使用，使得地球的原油日漸枯竭，根據 Aydoğan (2020)的預測地球的原油將於 50 年內枯竭。另外，根據 Shafiee and Topal (2009)的研究無論是根據他們的模式或是 Klass 模式或消耗/庫存比模式，原油將會於 40 年枯竭。Greene, Hopson and Li (2006)將原油分為傳統原油和非傳統原油(例如：油砂 oil sands,油頁岩 oil shale)，他們估計到 2050 年主體的非傳統原油尚不需要被開採，但是他們建議現在投入其他能源的研究並不太早。雖然有專家不同的看法，如 Blumsack (2020)所指出原油不會枯竭，但是 21 世紀勢必會朝向減低原油的使用而改用更清潔和有效率的能源，例如：風能、太陽能。但這些能源的使用將提高成本。解決原油枯竭的另一種可能就是對目前的原油提煉所產生的其他液態燃料作有效的利用。己烷就是其中的一種燃料。

市面上常見的替代能源是液化石油氣(又稱為液化瓦斯，Liquefied petroleum gas 英文簡稱 LPG)。液化石油氣係由原油煉製過程中所析出的丙烷與丁烷混合而成。它在常溫常壓下為氣體，經加壓或冷卻後變為液體，通常是裝入鋼瓶中供用戶使用。液化瓦斯流出容器就會變成氣體，熱值每公斤約 10720 千卡。瓦斯漏氣時，當空氣中混入 1.8~9.5%的液化石油氣，遇到火源便會產生燃燒或爆炸(Natural Gas Advocacy Program, 2011)。由於瓦斯桶的瓦斯用完需要叫送，不是那麼便利，為解決此一問題，因此，天然瓦斯應運而生。

天然氣俗稱天然瓦斯，由瓦斯公司敷設管線供用戶使用。它係古生物遺骸長期沈積地下，經慢慢轉化及變質裂解而產生之氣態碳氫化用物。其主要成份為甲烷，並含有少量之乙烷、丙烷、丁烷等碳氫化合物及少量之不燃性氣體。台灣地區瓦斯公司所供應之天然氣熱值約在每立方公尺 8900 卡至 9900 千卡之間。當空氣中之天然氣含量達 5~15%，遇到火源即會引起燃燒或爆炸(Natural Gas Advocacy Program, 2011)。

液化石油氣與天然氣完全燃燒時，產生無毒之二氧化碳，不完全燃燒時則會產生有毒之一氧化碳。天然氣與液化石油的氣熱值和價錢之比較如表 1(Natural Gas Advocacy Program, 2011)。液化石油氣 20 公斤熱值 = 10,720 仟卡/公升 X 20 公斤 = 214,400 仟卡，而此熱值等於 214,400 仟卡 ÷ 9,000 仟卡 = 23.82 度的

天然氣熱值，液化石油氣 20 公斤每桶售價約 633 元，天然氣每度售價 10.85 元，如果使用天然氣僅需 10.85 元 X 23.82 度 = 259 元就可產生相當液化瓦斯 20 公斤的熱值。故若不計天然氣瓦斯表的押、租金等費用，使用天然氣較液化石油氣節省約 59%。

表 1. 天然氣與液化石油的氣熱值和價錢(Natural Gas Advocacy Program, 2011)。

	熱值	售價	備註
天然氣(每度=每立方公尺)	9,000 仟卡	10.85 元	左列二項售價請依中油排價適時調整(Shinshing Natural Gas Co., Ltd., 2020)。
液化石油氣(每公斤)	10,720 仟卡	31.65 元	家用 20 公斤每桶約 633 元 (Monthly report on the average price of domestic LPG in counties and cities, 2020)

另一種可能的替代能源是己烷。它的熱值是 10,360 千卡/公斤，其熱值稍低於液化石油氣的 10,720 千卡/公斤(這是就著在兩者液體狀態下，每公斤而言)。但是沒有人拿它來作燃料，或許是因為它量太小，因此多作溶劑用。己烷的密度是 0.655g/ml，價格 39.8 元/公升(Solvent price list, 2020)。PE 塑膠桶內裝的液態己烷約 16 公斤，因此每桶液態己烷的成本是 16 公斤/(0.655 公斤/公升)*39.8 元/公升=972 元，產生的熱量 16*10,360=165,760 千卡，每元液態己烷產生的熱量為 170.5 千卡。相較於每元天然氣產生的熱量為 9000/10.85=829.5 千卡，其每元效率不及天然氣的 1/4。但是，相較於液態瓦斯產生的熱量 10720 仟卡/公斤 / 31.65 元/公斤=338.7 千卡不及近 1/2。若以每千卡所需要的成本計算，液態瓦斯需要 1/338.7=0.00295 元，己烷需要 1/170.5=0.00587 元，使用己烷貴(0.00587-0.00295)/0.00295=98.8%。由於己烷可以回收，根據業界估算，摻入回收己烷的複合己烷，可使成本降至 25 元/公斤，如此，複合己烷的燃燒成本與液態瓦斯相當。另外，目前的桶裝瓦斯的燃燒溫度約 800℃，而複合己烷的燃燒溫度約 1000℃，因此，可以節省(1000-800)/800=25%的烹煮時間。

己烷在常溫常壓下呈液態，是良好的有機溶劑，被廣泛使用在化工有機合成、機械設備表面清洗去污等環節，例如：PCB 電路板的銲錫清洗。但其具有一定的毒性，會通過呼吸道、皮膚等途徑進入人體，對人體產生侵害。己烷也可以作為均質壓燃引擎(Homogenous charge compression ignition, HCCI, engine)的燃料(Aydoğan, 2020)。均質壓燃引擎是一種新的汽車引擎，它是汽油引擎和柴油引擎的綜合體，具有兩者的優點：低汙染排放、高燃燒效能、低製造成本(John's Journal - GM Makes HCCI a Reality, 2007)。

雖然己烷的每元效率不及天然氣的 1/4，且己烷的產量低，但是己烷可以回收再利用的。據此，本文其中一位作者嘗試用裝置在 PE 塑膠桶中的液態燃料-複合已烷取代傳統的瓦斯桶(Hsu and Hsu, 2009)。本產品已經作出雛形並且公開展示(Mega energy technology debut, 2016)並商品化，見圖 1。本產品的優點在於液態燃料因壓力低沒有氣爆問題、節省 25%烹煮時間，並且可以將瓦斯鋼瓶改為較輕的 PE 塑膠桶，使用者可以自行填月充液態燃料，不需要叫瓦斯行換新的鋼瓶瓦斯。該 PE 塑膠桶由空氣壓縮機、曝氣石和止油逆流裝置等所共同組成(Hsu and Hsu, 2009)。本創作因複合已烷安全高、操作便捷等,故無須擔憂瓦斯洩漏或瓦斯中毒、爆炸等危險。己烷作為替代能源，常溫常壓下呈液態，與液化石油氣和天然氣的氣態不同，對燃具並沒有特殊要求，但由於液態燃料-複合已烷在 PE 塑膠桶的壓力比 LPG 在鋼瓶的壓力低，因此，當一般爐具改用液態燃料-複合已烷為燃料時，瓦斯爐的爐心內的銅心孔徑需要用鑽孔調整為大一些。這個動作可以由受訓練過的經銷人員來調整。如果使用快速爐則不需要調整，可以直接接管使用。關於使用天然氣的瓦斯爐，其爐心內的銅心孔孔徑也不需要調整。因此，在推廣己烷產品的行銷策略時，不需要考慮對燃燒條件的要求。

雖然本液態燃料具有上述優點，但是也有缺點如下：1. 每元效率不及天然氣的 1/4，2. 本產品的推出勢必消滅目前的鋼瓶瓦斯桶，這使得可能的經銷商(鋼瓶瓦斯行)卻步，因為瓦斯行將會損失他們的鋼瓶。因此，本產品勢必要找出一個好的行銷策略來突破困境。

圖 1. 液態瓦斯桶。

以下論文分段為：第二段文獻探討，研究現狀及存在的關鍵問題，突破性創新產品的特徵，以及如何將該產品引進產品主流的策略，過程中遭遇的矛盾，解決矛盾的萃智手法以及行銷策略 4P 的應用。第三段建立策略和矛盾現象以及解題過程，提出具體行銷策略。第四段結論以及未來的展望。

2. 參考文獻

液化石油氣(LPG)是一種用途廣泛的燃料，在城市公用事業及居民用氣方面占有相當的比例，由於 LPG 鋼瓶供應靈活，特別適合於城市郊區、鄉村、農村、工商業用戶(如金屬產品的熔化、鍛壓、軋製、熱壓及表面處理等工藝燃料；日用、化工、建築及電器絕緣陶瓷等工藝燃料(Hsu, 2021))及敷設天然氣管道不容易到達的地方使用(Zhang, 2020)。LPG 是屬於甲 A 類火災危險品，當它在液相時是不可燃的，但是，當它變成氣相時，閃燃點(flash point)非常低(-156°F) (Is propane flammable? 2020)，容易燃燒。它在常溫和 6 個大氣壓下鋼瓶內儲存時為液相，流動時由於摩擦非常容易產生靜電，極易發生火災或者爆炸事故(Sun, Zhang, Lu, et al.. 2021)。由於 LPG 容易引起火災，因此在歐洲家用的 LPG 鋼瓶或是 AMSE 容器在儲存時都有嚴格管制。例如：LPG 鋼瓶若放在住屋戶外，必須離開靜電引爆源(例如窗型冷氣)至少 10 英尺。如果住戶需要儲存數個鋼瓶，鋼瓶的外圍必須設置防火牆，防火牆的邊緣與最近的鋼瓶至少距離 3 米以上；而 LPG 的 ASME 容器除了必須離開靜電引爆源(例如窗型冷氣)至少 10 英尺，還必須安置在離開住戶土地邊境至少 10 英尺內，如果安裝數個 AMSE 容器，每個容器的距離至少要保持 10 英尺以上(Murphy, 2012)。相較於 LPG，天然氣在使用上就簡單、安全許多，其唯一缺點就是埋設的管路成本高，如果沒有足夠的用戶，一般天然氣公司是不會埋設管路的。這也就說明天然氣大都在都會地區使用，而鄉村地區就常使用罐裝的 LPG。

除了安裝上的安全考量外，在使用上如果 LPG 或天然氣外洩，則使用天然氣也是較安全的，其相關數據如表 2。LPG 主要的成分是丙烷(Propane，C_3H_8)和丁烷(Butane，C_4H_{10})。當 LPG 或天然氣外洩時，天然氣的密度(0.56~0.65)比空氣(1)輕，因此，如果有合適的排氣，天然氣不會累積在室內；反之，LPG 的密度比空氣重，即使有排氣，外洩的 LPG 還是會累積在地表上，一旦濃度高於 2.2%，就非常引起爆炸。相對於天然氣的最低燃燒極限(氣體在空氣中比例) 5%，天然氣顯然在使用上比 LPG 安全。可是 LPG 的熱卡值遠優於天然氣(這是就著兩者在氣體狀態下，每立方公尺而言)，大約是 2~2.5 倍。

表 2. LPG 與天然氣的物理性質(Murphy, 2012)

物理性質	丁烷	丙烷	天然氣
氣體密度(空氣=1)	2.0	1.5	0.56~0.65
最低燃燒極限(氣體在空氣中比例)	1.8	2.2	5
最高燃燒極限(氣體在空氣中比例)	9.0	10.0	15
熱卡(MJ/m^3)	120	95	37~41

如果有一種燃氣，它沒有 LPG 使用上的危險性，並且具有更高的熱卡值，該有多好？這可以在鄉村使用，並且能改善安全性。已烷(Hexane，C_6H_{14})就是其中選擇。其物理性質如表 3。己烷的氣體密度(3)比空氣重(Density of gases, 2021)，因此在開放空間容易向下累積，但其熱值是 LPG 的 1.4~1.8 倍(這是就著兩者在氣體狀態下，每立方公尺而言)。相較於 LPG，己烷還有一個優點就是沸點高(69℃)；而丙烷和丁烷的沸點各為-42℃和-1℃ (Engineering ToolBox, 2003)。因此，在儲存 LPG 時，必須在常溫下使用高壓才能維持 LPG 在液態，而在儲存己烷時卻不需要使用高壓鋼瓶，只需要使用 PE 塑膠瓶即可。

表 3. 己烷的物理性質(Engineering ToolBox, 2003)

物理性質	己烷
氣體密度(空氣=1)	3.0
最低燃燒極限(氣體在空氣中比例)	1.1
最高燃燒極限(氣體在空氣中比例)	7.5
熱卡(MJ/m^3)	173.9

Christensen, Raynor and McDonald (2015)認為不是僅僅顛覆目前主流產品就算為突破性創新的產品。突破性創新的機制乃是：現有市場的主導者由於集中心力於對他們要求最多的顧客(通常也是賺取利潤最多的)，這些主導者試圖滿足並超越這些顧客，以致無暇顧到其他顧客區塊而忽略他們的需求。此時具有突破性創新技術的新的入場者，以較低的價格針對被忽略的客群滿足他們的需求，使他們得到市場的立足點。然後，新的入場者往上端市場移動，提供主要市場顧客的需求，並且保留原來的優勢。當主要市場顧客開始採用新的入場者的產品時，突破就發生了(Christensen, Raynor and McDonald, 2015)。為了說明突破創新模式，他們的圖重新繪製並說明如下。

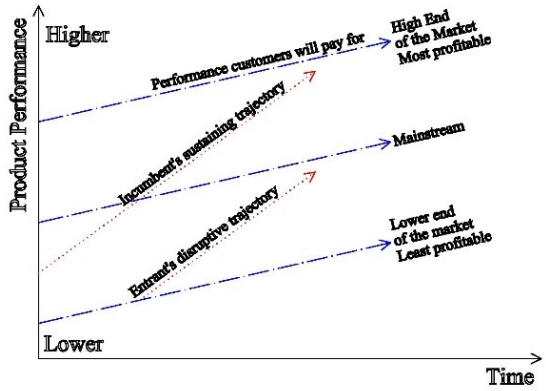

圖 2. 突破創新模式(Christensen, Raynor and McDonald, 2015)。

由圖 2 所知在當前主體顧客所要求的績效上，主導者的技術是遠勝於新的入場者的。由於主體市場的利潤優渥，主導者會將重心放在主體市場，並且不斷提升技術層次(例如產生功效 A 的技術)以獲得高端用戶的青睞，因此無暇顧到低端用戶的需求去製造一些低利潤低技術的產品。這使得新的入場者有機會將具有其他優勢的產品(例如產生具有功效 B 和 A 的技術，功效 A 的水準不如主導者的卻滿足低階市場的需求，功效 B 對主體市場沒有吸引力，卻對低階市場有吸引力)。當新的入場者的產品占據低階市場並且有機會獲得利潤來進一步發展功效 A 和 B 的技術，使得功效 A 的績效滿足大眾市場的需求並且挾帶功效 B 的優勢，就可以用低的價格進入主體市場。由於主導者不斷發展功效 A 的技術，並且超過大眾市場的需求，大眾市場就不願意多付錢買主導者的高端技術，而傾向於買滿足他們需求的功效 A 的技術，並且額外具有功效 B 的技術。此時，突破在大眾市場發生。這種情形會繼續發生在高端的市場，直到原來的主導者完全被逐出高端市場，此時原來新的入場者將成為新的主導者。這新的主導者所提供的產品同時具有功效 A 和 B。此時，產品的主要參數價值 MPV(Main Parameter Value)完全轉變從功效 A 轉為功效 B。

例如：Uber 一般被認為是一種突破性創新的服務，其實不然，因為，Uber 一開始就是進入計程車的主流市場(舊金山，一個完好服務的計程車市場)，而不是低階市場。雖然 Uber 提供一個優良的 App 平台連結要搭計程車的顧客和願意提供服務的 Uber 司機，並且收費透明和安全，還可以對司機的服務作評價，這些都是創新技術，並且獲得極大成功，擴展到全世界，但是，這些都不能足夠將 Uber 稱為突破性創新的服務(Christensen, Raynor and McDonald, 2015)。

然而，電爐生產的小型煉鋼廠 Minimill steel making 是一種突破性創新產品(Christensen, 2000)，它開始於 1960 年的中期。小型煉鋼廠將廢鋼在電爐裡熔化，然後用連續澆鑄形成小鋼胚(billets)，之後經過壓延、擠壓等過程形成鋼片(steel plate)、鋼板(steel sheet)、鋼棒(steel rod)、鋼條(steel bar)等。它的規模是大煉鋼廠的十分之一。他們是將鐵砂、其它金屬原料放在高爐熔化成鋼水，經由製胚過程澆鑄成鋼胚(slab)，再經過熱壓、冷壓、裁切成不同規格的鋼製品。兩者在連續澆鑄和壓延過程非常相似，其差別僅在於：高爐(blast furnace)的尺寸，大煉鋼廠的高爐甚大於小型煉鋼廠的。在 1995 年小型煉鋼廠生產一噸(ton)鋼需要 0.6 人工小時，而大型煉鋼廠需要 2.3 人工小時。

由於小型煉鋼廠的投入原料是廢鋼，因此，初期的冶金技術不好使得鋼品品質不高，僅能用於低階的鋼品，如鋼筋(rebar)。對於大煉鋼廠而言，鋼筋是低階產品，品質要求不高，利潤低而且需要鋼筋的客戶忠誠度低，隨時可以因價格改變買主。因此，這正合小型煉鋼廠的市場。當他們完全占有鋼筋市場後，這些小型煉鋼廠，例如 Nucor(The Nucor Story, 2013)和 Chaparral，開始努力改善品質，朝著更有利潤的上層市場邁進。如圖 3 所示，在 1980 年，他們攻占了 90%

的鋼筋市場並且據有 30%的鋼條(bars)、鋼棒(rods)和角鋼(angle iron)市場。由於這些市場對於大煉鋼廠而言並沒有太多利潤，在 1980 年代中期就全部由小型煉鋼廠占有。這時他們開始進攻結構鋼梁(structural beams)的市場，並於 1995 年完全攻占。最後剩下的高端鋼品是鋼片(sheet steel)，它是用於汽車(cars)、罐頭(cans)和電器(appliances)，這些產品要求極高的冶金品質，並且願意付高額的價格。

雖然大型煉鋼廠失去這麼多的市場，但在 1980 年代他們卻賺了許多錢，因為他們專注於高端市場。他們將品質不斷提升滿足高端用戶的需求而賺取高額利潤。伯利恆鋼廠(Bethlehem Steel)在 1986 年的市場價值是一億七千五百萬美元(175 million)，在 1989 年是二十四億美元(2.4 billion)。這是因為他們投資 13 億美元於工廠與設備的研發。這也說明他們為何無心於較低品質鋼品的生產，即使讓給別人也無所謂。

這時，在 1987 年德國鋼鐵工業(Schloemann-Siemag AG)發展一種新的生產技術，連續薄胚鑄造(continuous thin-slab casting)。它從鋼液作成薄胚並且在不需冷卻下直接送入壓延製成，直接壓延熾熱的薄胚成鋼捲(coiled sheet steel)遠比傳統的壓延冷卻的鋼胚更簡單和省錢，並且建造一座薄胚鑄造的工廠僅需 2 億 5 千萬美元(250 million)，這僅有傳統大型煉鋼廠費用的十分之一。此外，薄胚鑄造的鑄造成本可以節省 20%。但是，它有一個缺點：產品表面不夠平滑，無法滿足高端市場對鋼片表面品質的要求，這使得大型煉鋼廠裹足不前。他們的鋼品製成品只有限於不要求表面品質的製品，如甲板構造(construction decking)、鋼管(pipes)、涵洞(culvert)和昆塞特小屋(Quonset hut, 2020)。這些製品不在意表面品質，只在意價格。因此，薄胚鑄造是一種破壞性的技術(disruptive technology)。伯利恆鋼廠在評估後放棄薄胚鑄造，但是小型煉鋼廠如 Nucor 沒有高端產品壓力，就直接在 1989 年建造世界第一座連續薄胚鑄造生產線，在 1996 年 Nucor 占據 7%的北美鋼片市場，藉著不斷提升品質，他們終於完全攻占高端市場，2003 年伯利恆鋼廠宣布破產(Bethlehem Steel, 2020)。

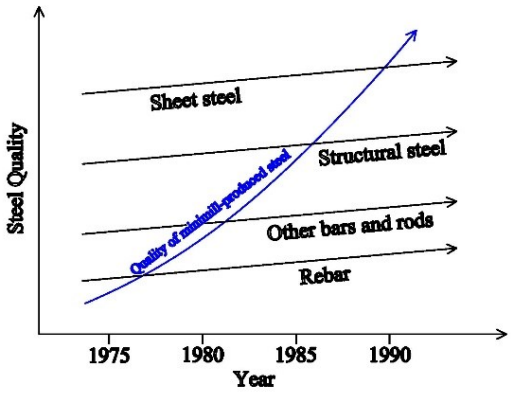

圖 3. 小型煉鋼廠的突破創新進展(Christensen, 2000)。

在解決服務創新時，經常會遇見兩個參數是互相衝突的。例如：在解決 101 大樓內的停車系統上(Lee, Wang and Trappey, 2015)，在原來停車的系統中 101 的住店廠商希望優惠採購商品的顧客停車小時的折扣，但是，這造成顧客尋找停車位的困惱。雖然，顧客可以在商店直接獲得折扣證明，但是，由於店員疏於詢問顧客以致忘記給他們證明，此時，等顧客採購他/她所需要的物品後，她們必須到一樓或 B1 的服務中心獲得停車折扣證明，由於停車的位置是 B3, B4 和 B5，而靠近服務中心的電梯在 B3, B4 和 B5 的出口並不一定靠近停車的位置，造成顧客不容易找到車子。這裡為了提升客製化的服務(服務的彈性 35，service flexibility)，就造成了另外一個服務參數，等候時間(尋車的等候時間)25 或生產力(服務績效，如有效率的尋車和付款便利)39，的惡化。根據矛盾矩陣可以找出兩組發明原則 35, 28 以及 35, 28, 6, 37。接著，將這些原則對應的服務創新列為表 4 並且以第一組發明原則 35, 28 細說如下。

表 4. TRIZ-based 的服務創新原則(Chang and Lu, 2009)。

原則	操作性定義	舉例說明
06. 多面性	a. 製造一個多功能的物體或結構減少其他物品的浪費。 b. 使用標準化特性產品。	a. 整合多種功能於一種 App 中(例如：購買商品、停車折扣、停車位置記錄和引導等)
28. 取代機械系統	a. 以感應系統取代機械系統。 b. 利用磁場電場使物體相互影響。 c. 改變靜電場為移動場。	a. 藉由智慧停車系統辨識並記錄車牌和停車位置。 b. 客製化的停車位置引導。
35. 特性的轉換	a. 改變物體的物理現象(如：濃度、溫度、壓力) b. 改變其彈性程度 c. 改變參數	a. 記錄車牌和停車位置。 b. 即時辨識和記錄車牌。
37. 熱膨脹	a. 使用熱膨脹材料 b. 如果已使用熱膨脹材料，利用多複合熱膨脹材料(具有不同熱膨脹係數的材質)	a. 對於某些常客(熱中來 101 採購)給於一些驚喜服務，例如印有 101 logo 的生活用品(浴巾、帽子、瓷碗、7/11 禮卷等等)或是專人提行李服務。

一、欲改善參數 35「彈性服務」且避免惡化參數 25「尋車的等候時間」，可以採用服務創新原則 35 與 28。

●原則 35：特性的轉換

特性轉換是改變事物的物理狀態、濃度或溫度。在服務上的應用是改變記錄車牌和停車位置以及辨識車牌的方式。傳統的方式是用筆記或記憶。雖然 Google map 提供新的尋車功能，但是，這是需要網路支援。在 101 大樓的地下室網路一般是缺乏或不足的。如有在每一個地下室的入口提供電子螢幕地圖，標示停車位置號碼和本人的相對位置將很容易的尋車。從筆記(硬體)的方式到電子螢幕地圖(軟體)的改變，將可加速尋車，解決矛盾問題。

●原則 28：取代機械系統

取代機械系統是用感應系統(如磁場、電場)取代機械系統。在服務上的應用是利用非實體的(聲音、光、顏色、氣味)取代實體的。可以在停車位置上方安置一個發光體和蜂鳴器，在停車場的入口處輸入車牌號碼和停車格號碼繳費後，系統會啟動發光體和蜂鳴器指引停車位置，甚至發光體的顏色和蜂鳴器聲音的內容可由顧客指定，這樣可以引導顧客到停車位置。等到車子離開後，系統會關閉發光體和蜂鳴器。另外，解決店員忘記給顧客折扣的證明，停車計費卡片可以結合收銀機讓每一筆交易都自動記錄到停車計費卡片上，這樣就都不需要問，這種金融訊號的傳輸就簡化了硬體的接觸。

為了要找出服務矛盾，需要作功能分析。傳統萃智的作法是建立元件的關聯性，建立彼此的功能關係，並依照功能的好壞分為有害功能和有用功能，接著依功能的強度分為過多、不足和充分三類。整個功能分析的目的是要消除或減弱有害功能或是刪減、合併元件使其仍維持系統的主要功能(Deng and Lin, 2013)。但是，Terninoko, Zusman and Zlotin (1998)提出另外一種功能分析法，就是用語意來表達。其主要內容為建立一個主要有害功能(Primary Harmful Function, PHF)和主要有用功能(Primary Useful Function, PUF)。並用一連串的有用功能和有害功能連接在一起，最後用一串問題述說刺激性的問題(provocative question)(其中有包含矛盾問題)來激發想出答案。其功能分析的示意圖如圖 4。其中有用功能用圓圈表示，有害功能用正方形表示。功能間的關係有造成(causes)、消除(eliminates)、需要(is required for)三種。每一個功能旁邊有數字，這數字標明提出改善該功能的問題。例如數字 1 是關於功能 PHF 的問題。接著，可以提出 1a. 在條件 UF4 下，找出一個消除、減少或避免 PHF 的方法。1b. 找出從 PHF 獲取利益的方法。2a. 找出一種提供 UF4 且能消除、降低或避免 HF1 的方法卻不會造成 PHF。2b. 找出強化 UF4 的方法。2c. 找出解決矛盾的方法：UF4 消除 HF1 確不會造成 PHF。由於功能 3 的分析與功能 1 的分析相似，本研究直接跳過功能 3 的細節而到功能 6。6a. 找出另一種提供 PUF 但卻不需要 UF1 和 UF2。6b. 找出強化 PUF 的方法。由於這種做法直覺，深受服務創新管理學者(Chai, Zhang and Tan, 2005; Lee, Wang and Trappey, 2015)的喜愛。

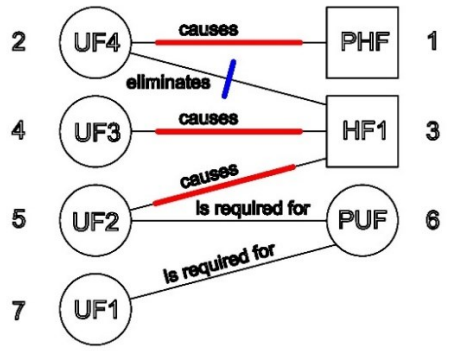

圖 4. Terninko 功能分析(Terninko, Zusman and Zlotin, 1998)。

在行銷策略上是以 4P(產品 Product, 價格 Price, 通路 Place, 推廣 Promotion)作為架構分析可能進入市場的策略。4P 是傑洛姆・麥卡錫(McCarthy, 1960)在 1960 年代強化企業行銷的方法。其中產品策略是指產品品質和標準、產品特徵、標籤、品牌名稱、定位和售後服務等等策略。價格策略是指訂價方式(依數量、顧客屬性、對顧客的價值、顧客的生活型態、在不同通路上[例如零售 Retail、中間商 Intermediary、批發商 wholesale]和季節調整)和付款方式等等。通路策略是指零售、中間商(形態、數目、責任)、批發商 wholesale、涵蓋區域、配銷渠道(distribution channels)、上架、連鎖店的專櫃、運輸形態、交貨時間表(delivery schedule)和物流基礎設施(logistic infrastructure)等等。推廣策略是指廣告(預算、媒體、工具、契約長度、契約形態)、人員推銷、口碑行銷、社群行銷、直銷和公關等等。

以生產者為導向的 4P 的行銷模式曾遭受到客製化、小量多樣的市場變遷所衝擊，因而有以顧客為導向 4C(Lauterborn, 1990) (顧客需求 consumer wants and needs, 成本 consumer’s costs to satisfy that want or need, 便利 convenience to buy, 溝通 communication)觀念的產生與其對抗。然而尹坤和李欣(Yin and Li, 2015)認為 4P 的策略適合於製造型企業而 4C 服務業。在完全壟斷(如電力、自來水或專利性產品)及技術門檻較高的寡頭壟斷市場(如汽車、手機)，企業處於主導地位，4P 策略較為適用。但是在充分競爭市場(如米、餐飲、生活家電)中 4C 策略更為重要。楊英賢等人(Yung, Lin and Lin, 2018)將 4P 策略用於保健食品-中草藥市場的綠豆篁；Halim, Halim and Felecia (2019)將 4P 策略用於印尼某餐廳的市場行銷，並且用大數據即時提供經營者動態的行銷策略；Jimenez-Asenjo and Filipescu (2019)將 4P 用於西班牙的葡萄酒行銷到中國，這是跨國性的成功行銷案例；另外，Halaj and Brodrechtova (2018)將 7P 和 7C 用於歐洲三國的森林資源的行銷決策，其中 7P 和 7C 是 4P 和 4C 的延伸。

3. 建立行銷策略

如前所述本液態燃料主體是己烷，其燃燒成本與目前桶裝瓦斯相同，並且有容易填充和低壓不氣爆的優點。因此，將本產品定位為突破性創新科技產品是完全符合 Christensen (Christensen, Raynor and McDonald, 2015; Christensen, 2000)的定義的。那裏說突破性創新科技產品必須有一特徵功能是優於其它類似產品，但在主要市場上仍不符合市場對其品質的需求。本研究液態燃料瓦斯桶的優點是低壓不氣爆，而桶裝瓦斯桶會有氣爆問題。但是，瓦斯桶爆炸的機會很低，一般都是外界的熱源引爆瓦斯桶，也就是先有瓦斯氣爆，然後造成瓦斯桶引爆。不論是桶裝瓦斯或是天然瓦斯都有氣爆問題。而當空氣中天然氣濃度達 5~15%，液化石油氣濃度達 1.95~9%時，若被火源引燃便會引發爆炸(Gas explosions are mostly caused by human negligence, 2010)。即使用己烷為基礎的液態燃料經氣化後跑進空氣中達到一定濃度也會氣爆。但是，己烷在室溫的氣態密度是 3.79 kg/m^3 (Density of gases, 2021)，比空氣的重。因此，即使合適的通風，己烷氣體會往地面累積。這如同液態瓦斯(丙烷和丁烷的混合物)的氣態密度(1.94~2.56 kg/m^3)比空氣的重(Density of gases, 2021)，所以瓦斯氣不容易排出，因此容易累積到一定濃度，一但遇到火源就會產生氣爆。

因此，就著突破性創新科技產品而言，液態燃料的特徵功能在於低壓儲存，不需要高壓鋼瓶，因此，重量輕，容易搬運，比用高壓鋼瓶的 LPG 安全。但是，它的氣態密度(3.79 kg/m^3)比空氣的重(1.27 kg/m^3)(Density of gases, 2021)，容易向地面累積，在相對密閉空間內即使有合適的通風需要注意如果己烷氣體外洩濃度過高而產生氣爆，但其燃燒功率比瓦斯桶相當、烹煮時間節省約 25%。就著目前的主流市場而言，由於己烷的生產量不多，可能無法滿足一般家庭的需求量。但是，就著餐飲業而言應該可以滿足。特別是在都會地區的餐廳的廚房，液態燃料應該是他們需要的。

現在潛在的顧客已經標明，那要如何行銷呢？本文的作著之一曾經請行銷公司拍攝一支短片(Cross-Strait Times: Mega Energy Technology Debut to Reduce Fuel Costs by 15%, 2016,)說明液態瓦斯的優越性，但是效果不佳。該短片請廚師來用液態燃料來煮菜，說明本產品的實用性，但是，沒將本產品的優越

性表明出來，就是己烷低壓儲存，不需要高壓鋼瓶，因此，重量輕，容易搬運。因此，第一種的行銷策略就是製作大約 2 分鐘的微電影或 2D 動畫來說明此優點。使用語言有英文、中文、廣東話、印尼文、印度文和葡萄牙文。根據(Liquefied petroleum gas, 2020)全世界需要液態瓦斯 Liquified Petroleum Gas(LPG)的國家或地區主要有印度、中國、香港特別行政區、印尼和巴西等。本文僅就著香港特別行政區如何行銷液態燃料作說明。

根據 Liquefied petroleum gas (2020)香港特別行政區一直使用 LPG 作為標準的煮飯燃料。但是，由於 Town gas 天然氣公司的不斷擴張，使得 LPG 的使用量下降 24%，即使這樣，LPG 仍是郊區市民最常用的烹煮燃料。很明顯，香港特別行政區地小人稠，他們的家用或餐廳的廚房是較小而且相對密閉的。因此，本產品如果能夠銷售到香港特別行政區一定非常受歡迎。問題是桶裝液態燃料如何進口到香港特別行政區。當然，由台灣海運過去是可行方案，但是會增加成本。最好的辦法是由深圳進去，這是最便宜的。深圳有許多工業區，利用中國的己烷生產量可以充分的供應香港特別行政區的需要。因此，在中國某地(最好靠近深圳)能有合作的廠商或是直接買斷本產品專利技術的瓦斯公司從事生產和行銷的工作，而本產品則提供技術的指導，這是最直截了當的作法。由於在中國做生意需要講究關係(Jimenez-Asenjo and Filipescu, 2019)，這種錯綜複雜關係的打點由當地人處理最佳。因此，賣斷專利給當地客戶是最穩當、簡單的作法。

進一步的功能分析可以幫助本研究想出更多的點子。由台灣運送液態燃料到香港特別行政區所產生的功能分析圖如圖 5。

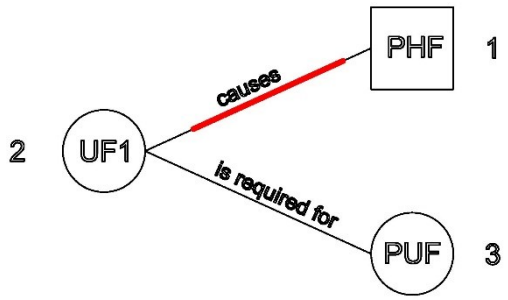

圖 5. 液態燃料桶的功能分析。

圖 5 中的主要有用功能 PUF 是供給省時、重量輕、低壓儲存的燃料，主要有害功能 PHF 是運費貴，有用功能 UF1 是海運液態燃料。要提供香港特別行政區居民省時、重量輕、低壓儲存的燃料需要從台灣用海運運送液態燃料，但是這造成運費貴。以下針對三個功能提出以下刺激性的問題。

1a. 找出在 UF1 下一個消除、降低或避免 PHF 的方案。
1b. 找出一種可以由 PHF 獲得的益處。
2a. 找出 UF1 的替代方案能夠滿足 PUF 但是卻不會造成 PHF。
2b. 找出強化 UF1 的方案。
2c. 找出下列的矛盾解。UF1 滿足 PUF 卻不會造成 PHF。
3a. 找出一種方案來提供 PUF 但卻不需要 UF1。
3b. 找出強化 PUF 的方法。

以下是提出的解答。

1as. 只運送 PE 塑膠桶。由於 PE 塑膠桶是低壓桶，可以當作一般物品運送。到了香港特別行政區再將己烷填裝在 PE 塑膠桶內，這樣就可以降低運費和提升運輸的安全。

1bs. 由於由 PHF 獲得的益處是發明原則 22 轉有害為有利的應用，我們就使用水準思考(lateral thinking) (De Bono, 1991)來跳脫思考瓶頸。首先，PHF 是運費貴，我們就想怎樣能不貴，不是在設備上改善使其不貴，乃是在烹飪食物時不貴。因此，激發使用者想出一些不需要煮食物的料理，例如：沙拉。另外，熱傳導效能高的鍋子或是悶燒的鍋子也是可以考慮。當鍋子是熱傳導效能高時，也可以節省成本。另外，時間就是金錢。相較於液態瓦斯己烷的烹煮時間可以節省 25%。目前在市面上已有熱傳導效能高的鍋子，因此，觸發可以異類結盟(液態燃料+熱傳導效能高的鍋子)共同行銷的策略。

2as. 可以在深圳製造 PE 塑膠桶並且由深圳購得己烷，然後將兩樣送至香港特別行政區後再將己烷填裝在 PE 塑膠桶內。

2bs. 將己烷和 PE 塑膠桶由台灣分開運送至香港特別行政區。

2cs. 從原始的海運方案，首先形成一組技術衝突。根據 Creax (CREAX Innovation Suite, 2002)的管理矛盾矩陣要改善參數 26「便利 Convenience」，但卻惡化參數 12「供應成本 Supply cost」，可以對應到 4 個發明原則 30(Thin and Flexible)、2(Take out)、3(Local quality)、5(Merge)。2c 的題目要改善的參數是時間和重量，而造成的惡化參數是成本。但是在 Creax 內並沒有完全對應到「省時和重量」和「成本」。只能找到接近的參數「便利」和「供應成本」。這 4 種發明原則對應的管理策略如表 5。接著，可以使用這些發明原則於目前處理方法：由台灣海運，並加以改善。由薄膜的原理 30 想出最薄的運送方式就是專利的授

權。將專利授權給香港特別行政區的商人，由他來處理製造和配銷的問題，這樣就可以提供安全的液態燃料，同時也降低運送成本。另外，合併原理 5 也可激發方案如合併巨億能源公司與香港特別行政區的公司，一同來開發香港特別行政區的市場。合併的方式有巨億公司買下香港特別行政區某公司直接在香港特別行政區經營液態燃料，或是考慮和中國某公司合作共同買下香港特別行政區某公司一同開發香港特別行政區市場。

3as. 由於香港特別行政區、深圳、澳門特別行政區、廣州都在一個生活圈內，或許可以擴大液態燃料的服務範圍，從其中找出更合適的合作對象一同開發這四個地區的市場。由於量變大，生產 PE 塑膠桶的成本可以降低，整個運費也可以降低。另外，可以考慮將 PE 塑膠桶作的更小一點適合地小人稠的香港特別行政區使用。己烷的銷售可以與當地的加油站合作來銷售，使用者就會很方便的購買己烷自行填裝。這樣會使運送成本降的更低。

3bs. 由於己烷讓人聞久了會造成不舒服的感覺。為了強化液態燃料的自我填裝的優越性。合適的填裝己烷桶子(或容器)需要開發出來，讓填裝過程更加安全。

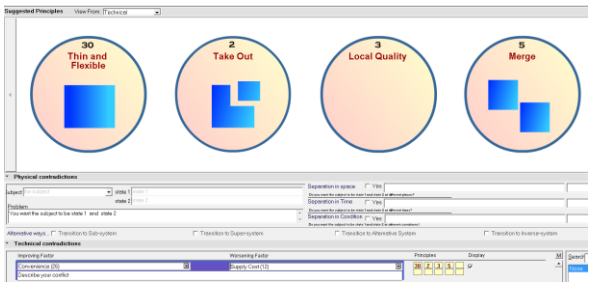

圖 6. CREAX(CREAX Innovation Suite, 2002)管理矛盾矩陣。

表 5. CREAX 的服務創新原則(CREAX Innovation Suite, 2002)。

原則	操作性定義	舉例說明
30. Thin and Flexible	A. Incorporate flexible shells and thin films instead of solid structures. B. Isolate an object or system from a potentially harmful environment using flexible shells and thin films.	1. 一人服務公司。 2. 使用信用卡而非現金交易。 3. 在辦公室使用活動屏風隔離外界的干擾。
2. Take out	A. Where a system provides several functions of which one or more are not required (and may be harmful) at certain conditions, design the system so that they are or can be taken out.	1. 打破部門的界線。(戴明 14 點原則第 9 點) 2. 消除標語和口號。(戴明 14 點原則第 10 點) 3. 將部分重要的行銷或廣告活動外包。
3. Local quality	A. Where an object or system is uniform or homogenous, make it non-uniform. B. Change things around the system (e.g. the environment)) from uniform to non-uniform. C. Enable each part of a system to function in locally optimized conditions.	1. 移除固定薪水制度。 2. 彈性工作時間。 3. 利用茶點時間作非正式的溝通。 4. 選擇靠近顧客的配銷中心。
5. Merge	A. Physically join or merge identical or related objects, operations or functions. B. Join or merge objects, operations or functions so that they act together in time.	1. 一票玩到底的遊樂區，給予消費者享有一次購足的樂趣。 2. 客服中心。 3. 多媒體。 4. 以搭售或折扣方式進行銷售。

以下用 4P 的觀點將上面的行銷策略整理為如下的 13 項：

表 6. 液態燃料服務創新的 4P 分類

4P	行銷策略
產品 Product	1. 由於香港特別行政區地小人稠，可以設計更小的液態燃料 PE 塑膠桶方便使用。 2. 需要開發能自行填裝己烷桶子(或容器)，讓填裝過程更加安全。 3. 與當地的加油站合作一同銷售己烷。
價格 Price	1. 將香港特別行政區、深圳、澳門

	特別行政區、廣州視為一個生活圈，共同銷售液態燃料己烷，並結合前面 3 個策略降低產品成本、提升使用方便性。 2. 使用區別價格。富足的地區，可以調高價格。產品外型可以依區域而不同，適合不同地區需要。例如：在中國的售價可以較低，並且配以較大的 PE 塑膠桶。 3. 強調液態燃料比液態瓦斯在的烹煮時間上可以減少 25%。
通路 Place	1. 專利授權給香港特別行政區的商人。 2. 巨億能源公司可併購香港特別行政區的公司，一同來開發香港特別行政區的市場。 3. 考慮和中國某公司合作共同買下香港特別行政區某公司一同開發香港特別行政區市場。 4. 在香港特別行政區、深圳、澳門特別行政區、廣州共同生活圈內找出合作夥伴一同開發這四處地區的市場。
推廣 Promotion	1. 用微電影或 2D 動畫來說明液態燃料己烷在使用上省時、重量輕的優越性。並用不同語言向需要的市場播放。這些國家或地區主要有印度、中國、香港特別行政區、印尼和巴西等。 2. 製作迷你版的 PE 塑膠桶方便在台灣的相關外籍人士免費使用。 3. 可以異類結盟（液態燃料+熱傳導效能高的鍋子）共同行銷。

本文章指出己烷產量少和成本高，並給出回收利用的解決方法，以下進一步討論能否在數量和品質上滿足市場需求。根據網路的市場分析，2020 年 LPG 的生產量是 320 百萬公噸 (Argus, 2021)，而己烷的生產量只有 1.75 百萬公噸 (Businesswire, 2021)。己烷只佔 LPG 產量的 0.55%。很明顯，己烷無法完全取代 LPG。但是，就著己烷在香港特別行政區的需求量，或是在香港特別行政區、深圳、澳門特別行政區、廣州都在一個生活圈內的需求量，這是可能的。因為一般台灣四口家庭用 20 公斤的桶裝瓦斯筒至少可以用 1 個月(這包括一天 2 餐，洗澡等)。2021 估計在香港特別行政區、深圳、澳門特別行政區、廣州人口約 4 千萬(香港特別行政區 7.5 M、深圳 12.6M、澳門特別行政區 0.7M、廣州 18.7M，全部 39.5M) (Guangzhou Resident Population, 2021)，假設就著烹煮用途，這 4 千萬人會使用 LPG 的比例是 25% (其餘的人使用天然氣) (Liquefied petroleum gas, 2020)，則每年的需求量是 40,000,000 人*0.25/4(人/戶)*20 公斤/月/0.655(公斤/公升)*12 月/年/1,000,000(公升/公噸)=916 公噸。中國 2020 年 LPG 的生產量是 44.48M 公噸，而 LPG 和己烷都是由煉油製程產生的，己烷與 LPG 的生產量比是 0.55%，因此，可以粗估己烷的年生產量是 44.48 M*0.55%=244640 公噸。相較於需求量 916 公噸，中國對香港特別行政區、深圳、澳門特別行政區、廣州一個生活圈內的需求量的供應上沒有問題，在質量上由於己烷的煉製是標準製程，所以也沒有問題。但是，中國如果供給己烷有問題，也可以由進口解決。

4. 結論與展望

雖如 Blumsack (2020)所指出原油不會枯竭，但是 21 世紀勢必會朝向減低原油的使用而改用更清潔和有效率的能源，例如：風能、太陽能。但是，這些能源的使用將提高成本。解決原油枯竭的另一種可能就是對目前的原油提煉所產生的其他液態燃料作有效的利用，其中一種液態燃料就是己烷。

本文探討如何行銷以己烷為基礎的液態燃料。該燃料盛裝於 PE 塑膠桶內，具有低壓不爆炸的優點。其燃燒成本與液態瓦斯一樣，但節省 25%的烹煮時間。液態燃料的特徵功能在於省時、重量輕和低壓儲存。但是氣態時密度(3.79 kg/m^3)比空氣的(1.27 kg/m^3)重(Density of gases, 2021)，如果己烷氣體外洩容易向地面堆積，在相對密閉空間內即使有合適的通風也可能發生濃度過高而產生氣爆。就像液態瓦斯氣體的比重比空氣重(1.94~2.56 kg/m^3)，容易堆積在地面上，不易揮發造成濃度增加，等到濃度到達一定程度，一遇到火源就會產生氣爆。因此，根據 Christensen, Raynor and McDonald (2015)和 Christensen (2000)就著特徵而言，它是一種突破性創新產品。它的優點是己烷是低壓儲存，重量輕，比用高壓鋼瓶的 LPG 安全。並且它的燃燒成本比液態瓦斯一樣，但時間減少 25%。相對於主流廚房用的燃料而言，它的缺點是，產量不及液態瓦斯，品牌知名度不高。目前使用液態瓦斯的主要市場有：印度、中國、香港特別行政區、印尼和巴西等國或地區。

根據 Christensen, Raynor and McDonald (2015)和 Christensen (2000)對突破性創新產品的行銷策略建議，要將市場設在需求量少的低階市場，這些市場不在乎品牌知名度，只在乎方便性和時間。本研究特別以香港特別行政區這個市場作策略分析。這是因為香港特別行政區地小人稠、高度商業化，特別重視方便性和節省時間。

首先，本研究藉著腦力激盪想出一種行銷策略：藉由海運，將裝有液態燃料的 PE 塑膠桶送到香港特別行政區。或是在中國某地(最好靠近深圳)找到能合作的廠商或是直接買斷本產品專利技術的瓦斯公司從事生產和行銷的工作，而本產品則提供技術的指導。接著，針對液態燃料的 PE 塑膠桶送到香港特別行政區的方案作 Terninko, Zusman and Zlotin (1998)提出的萃智功能分析，衍生出 7 個問題。其中有些問題是管理衝突問題，然後，提出創意性的解答。管理衝突是藉由 CREAX 軟體提供觸發解的 4 個發明原則，然後，根據發明原則想出解決策略。之後，用 4P 將解答分類共得到 13 組策略，結果如表 6。

以下列舉其中 12 方案如下：

1. 液態燃料 PE 塑膠桶可以用更小的桶子設計適於香港特別行政區的生活型態。
2. 合適的填裝己烷桶子(或容器)需要開發出來，讓填裝過程更加安全。
3. 己烷的銷售可與當地的加油站合作一同銷售。
4. 將香港特別行政區、深圳、澳門特別行政區、廣州視為一個生活圈，共同銷售液態燃料己烷，並結合前面 3 個策略降低產品成本、提升使用方便性。
5. 使用區別價格。富足的地區，可以調高價格。產品外型可以依區域而不同，適合不同地區需要。例如：在中國的售價可以較低，並且配以較大的 PE 塑膠桶。
6. 標明液態燃料與液態瓦斯的烹煮成本相同，但時間可以減少 25%。
7. 專利授權給香港特別行政區的商人。
8. 合併巨億能源公司與香港特別行政區的公司，一同來開發香港特別行政區的市場。
9. 考慮和中國某公司合作共同買下香港特別行政區某公司一同開發香港特別行政區市場。
10. 用微電影或 2D 動畫來說明液態燃料己烷在使用上省時、重量輕的優越性。並用不同語言向需要的市場播放。這些國家或地區主要有印度、中國、香港特別行政區、印尼和巴西等。
11. 製作迷你版的 PE 塑膠桶方便在台灣的相關外籍人士免費使用。
12. 可以異類結盟(液態燃料+熱傳導效能高的鍋子)共同行銷。

關於己烷產量少和成本高的問題，或許由以下方式解決。就是回收用在工業界的己烷作為液態燃料的來源，這可以減少環境污染和解決天然己烷生產量低的問題。不但如此，也可以降低液態燃料的成本。如果回收技術成熟，這或許可以在將來幫助己烷進入家庭燃料的主流市場。

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Biography

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Applying TRIZ Evolutionary Trends to the Innovative Product Design of Refrigerator

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Abstract

Household refrigerators have become an important appliance to family life. In recent years, the domestic brands, facing fierce price competition, are difficult to increase the sales of refrigerator. The refrigerator market is also approaching saturation. To fulfill the needs of consumers, it is necessary to improve and enhance the innovative functionality of the product. Therefore, this study adopts the 37 evolution trends, the TRIZ tool proposed by D. Mann, takes the well-known brands, including Hitachi, Kolin, Panasonic, Sanlux Sanyo and Tatung, as the research objects, and collects the functional data of refrigerators according to the main purchase motivations of consumers. The four key motivations are "convenient", "space design", "temperature control" and "appearance", used to categorize and demonstrate the results of the evolutionary trends through radar charts, offering an overall understanding of the current status and limits of functional evolutions. With the application of 37 TRIZ evolution trends, some important contributions and conclusions are described as follows: (1) this study helps to understand the current status of functional evolutions of refrigerators, shown in the radar charts, and propose new concepts of innovative product design; (2) the I25 degrees of freedom and I30 design methods are key parameters with considerable potential in the evolution of refrigerator design; (3) the evolution results show that future products will have different usage modes according to individual user's needs and embrace the concept of refrigerator intelligentization.

Keywords: TRIZ, Innovative Product Design, 37 Evolutionary Trends

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運用 TRIZ 演化趨勢於冰箱產品創新設計之研究

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摘要

家用冰箱已經成為家庭生活不可或缺的一個重要家電產品，近年來卻面臨東南亞進口產品競爭對手，採取價格競爭激烈手段，以及日系進口高單價產品來瓜分市場下，國內廠牌無法提升產品銷售量，目前冰箱市場已趨近飽和。若要掌握此消費者需求，除產品之穩定性外，須針對產品之創新功能性進行改善與提升，故本研究採用 D.Mann 所提出的 TRIZ 37 項參數演化趨勢工具，以國際牌、日立、歌林、聲寶、台灣三洋、大同為研究對象，進行冰箱功能資料收集，依照消費者主要選購動機「方便」、「空間設計」、「溫度控制」、「外觀」四項分類，將分類結果繪製出演化趨勢雷達圖，瞭解功能演化現狀與極限，以此作為未來產品創新參考。藉由 TRIZ 37 項參數演化趨勢，應用在冰箱功能面的發展的研究，完成以下初步的貢獻與結論：(1) 瞭解到目前冰箱在功能方面演化的現狀，並繪製成演化趨勢雷達圖，成功地提出尚未運用的演化參數，成功完成冰箱新產品構思；(2) 目前冰箱功能面上演化極限及潛力，在演化趨勢參數中 I25 自由度、I30 設計方法，具有相當大的演化潛力趨勢，故可透過這幾項演化趨勢構思出差異化商品；(3) 本研究發現使用者個人化需求來調整使用冰箱模式，以及冰箱智能化的概念，可作為日後冰箱製造業者創新開發之參考。

關鍵詞: 發明問題解決理論(TRIZ)、產品創新設計、37 項演化趨勢

1. 緒論

家用冰箱為家庭生活不可或缺的一個重要家電產品，由於其高普及率，面臨國內市場規模不足及國際廠商價格優勢，國內生產冰箱銷售狀況，幾乎是每況愈下。冰箱產業之功能已屬於成熟產業，目前市場已趨近飽和，市場需求大多來自替換舊產品為主，而替換之原因除原本舊產品故障外，對產品之性能之不滿意亦是另一主要因素，若要掌握此消費者需求，除產品之穩定性外，須針對產品之創新性進行改善與提升。

家電業者也留意到市場脈動，為了滿足消費者對冰箱的需求性，在冰箱「性能」上不斷提升，研發更貼近使用者習慣的冰箱，提升使用的方便性，以及保鮮性能年年推陳出新，冷凍、冷藏都能鎖住食物的原味，抓住消費者的心；在「設計」方面，冰箱外觀、色彩、設計感符合居家設計風格受到消費者青睞外，消費者同時也重視「尺寸符合家中需求」，主要是生活習慣改變，民眾習慣一次購足食材，導致消費者對「大容量」需求提高，不僅冰箱追求內壁變薄，還需要將小空間靈活運用。因此，「方便性」、「溫度控制」、「外觀」、「空間設計」為消費者在選購冰箱時，最先優先考慮的因素，這四項因素也考驗著家電業者不斷推出創新的產品，隨著時代變遷滿足消費者的需求。

本論文主要研究目的在於探討冰箱功能演進趨勢，有別於過去大部分學者以專利、功能面探討出產品功能演化趨勢，本論文是以消費者角度觀察冰箱功能演變過程，從「方便」、「空間設計」、「溫度控制」、「外觀設計」四種構面，去探討國內冰箱產業創新功能演變過程，以 Panasonic 國際牌、HITACHI 日立、Kolin 歌林、SAMPO 聲寶、SANYO 台灣三洋、TATUNG 大同為研究對象，收集各廠牌歷年廣告文宣資料，運用學者 D. Mann 所提出 37 項演化趨勢理論，依本研究四種功能構面「方便性」、「溫度控制」、「外觀設計」、「空間設計」做分類，並將分類結果繪製成演化趨勢雷達圖，瞭解目前冰箱功能所處演化趨勢的階段，再分析各演化參數的潛力與極限，推想符合市場需求且新創概念的冰箱。

2. 文獻探討

2.1 TRIZ 發明問題解決理論

TRIZ 創新發明解決理論(Theory of Inventive Problem Solving)，是由蘇聯學者 Altshuller，於 1946

年提出創新原理解決方法(Altshuller, 1999)。當時他在審核專利作業時，察覺到任何一種技術的創新過程中都有一定的程序跟步驟，Altshuller 分析了世界近 250 萬筆的發明專利進行長期的歸納與分析，發現不同領域界面對各種創新發明的問題，存在著共同的基礎問題與解決問題的基礎原則，利用這些發現進而整理出一套系統性的創新發明法則，並建立起 TRIZ 理論體系，掌握了這些規律，就能主動地進行產品設計並能預測產品的未來趨勢。

當一般人遇到特定問題時，會以自身的經驗，自身具備的技能，或是透過群眾腦力激盪的方式，尋找問題的答案，也就是從特定問題直接發想特定問題的解答，但這樣的方式很容易將問題發散，憑藉著有限的思維，不容易找到具完整性的答案。反觀於 TRIZ，是將特定問題點轉化成標準問題，透過 Altshuller 大量分析專利與案件所建構的 TRIZ 工具，得知標準解答，再將標準解答轉換成該特定問題解答，這就是 TRIZ 解決問題方法的基本流程。

在上述的基本流程下，Altshuller 與他的 TRIZ 團隊，陸續提出很多創新發明之問題解決分析工具，一般泛稱為 TRIZ 理論技術方法，包括 40 創意原則、ARIZ 發明問題解決演算法、理想性觀念、工程系統的進化趨勢、矛盾矩陣表及物質-場分析…等等。綜合來說，TRIZ 是一種應用前人的智慧與經驗，所發展出系統改良的方法；是一種自覺性演化的技術系統和解決工程問題的方法；也是一種消除工程衝突，而不抵消妥協的工具；更是無數發明家的知識與經驗，來增加工程人員知識創造力和解決問題技巧的方法。

2.2 TRIZ 技術系統演化趨勢理論與產品創新

TRIZ 技術系統演化趨勢理論(Patterns of Evolution of Technological Systems)是 TRIZ 眾多工具中的一種，Altshuller 從世界專利分析和研究，察覺到技術系統在結構上演化趨勢，及技術系統演化模式演化路線，每條演化路線是從結構演化的特點，描述產品技術所處的狀態序列，產品是如何從一種技術移轉到另一種技術，在新技術裡可能是性能價值提昇功能增加也有可能是成本降低，即產品延演化路線演化過程是新舊技術更替的過程，依據當前的產品技術所處狀態，經由設計可使其移動到新的狀態，有助於完成產品的創新設計和改善設計，同時在同一個工程領域中總結出的演化模式及演化路線，可以在另一工程領域中實現，即技術演化模式及演化路線具有可傳遞性，因此 TRIZ 理論不僅能預測技術的發展，而且還能展現預測的結果，實現產品可能狀態，對於產品創新具有指導作用，進而延伸應用在其他創新領域(Monteiro, 2012; Chiang, Yi & Chang, 2013; Govindarajan, Sheu & Mann, 2019)。

Altshuller (1984)透過大量分析專利與案件，得知每一個功能系統的演化並非隨機發生，而是依循著可預測的模式進行，所以先提出八大技術系統演化趨勢，分別為：(1)增加理想性：增加系統的有用功能，並減少系統的有害功能；(2)遵循生命週期階段演化：沿著技術系統演化（S 曲線）的四個階段，分別為嬰兒期、成長期、成熟期、衰退期，系統功能設計會有所不同；(3)系統元件非均衡發展：系統是由多個子系統所組成，每個子系統都有各自 S 曲線演化，並在不同時間達到演化極限；(4)增加動態與可控制性：為了適應不斷變化的環境，讓系統功能擁有更高的彈性或多樣性；(5)增加複雜性再簡單化：系統演化先是不斷增加功能及品質來滿足需求，經過一段時間後，再透過系統整合逐漸簡化；(6)部份耦合與非耦合：在相同性質的系統加入不同性質的系統，或是將不同性質的系統整合成同性質的系統，以尋求突破的解答；(7)從大系統到極小系統的轉換：系統逐漸地朝向縮小化和簡便化的方向演進；(8)減少人為參與增加自動化。

很多技術的進化可以依循著 Altshuller 八大技術系統演化趨勢來解釋，但實際上的運用，仍然有很多不足的地方。學者 Mann (2007)提出的 37 項技術演化趨勢，可分為空間（13 項）、介面（18 項）、時間（6 項）三大類，使用者透過三大類、37 項的演化趨勢，可以有效地決定技術系統未來的趨向，具有良好的可操作性、系統性和實用性，並經過實踐檢驗適合一般產品開發使用，以下表 1 至表 3 為各項演化趨勢的簡要說明。

目前關於家用冰箱創新的趨勢研究如下，Liu (2013)的調查研究發現，冰箱的發展趨勢主要來自於環保節能、智慧化、人性化的三大需求。因應環境變遷與政策規範下，冰箱在壓縮機與製冷技術上不斷地進行改良與創新，以達成節能與環保的目標；其次，隨著感測技術與通訊技術的進步，智慧化的冰箱根據溫度、濕度與使用者習慣，會自動調整運作模式，並搭配物聯網功能，讓冰箱可以與使用者進行資訊互動；再者，冰箱的發展也更貼近人性化需求，包括照明、外觀、結構、保鮮、靜音、省力等等，都為現代生活帶來便利與美好。另外，Lim (2020)則將現代冰箱結構分為六項要素，包括冰箱門把、冰箱門、資訊顯示、取水／冰口、家庭飲料櫃、

冷藏／冷凍庫，運用 TRIZ 40 個發明原則加以創新，其中運用分割原理(Segmentation)、非對稱原理(Asymmetry)，可增加冰箱門的數量，並搭配對開設計；運用合併原理(Consolidation)、球面化原理(Spheroidality)，採取無門把與弧線設計，增加冰箱的美觀度；運用部份或過度原理(Partial or Excessive actions)、回饋原理(Feedback)，可將原來較小的家庭飲料櫃，擴大為門中門的設計，並搭配透視的材質，可以即時察看內容物；最後，運用轉換維度原理(Transition into a New Dimension)，將冰箱嵌入廚房裝潢內，讓廚房具有整體的和諧性。歸結上述學者的研究成果，對照表 1 至表 3 的 37 項技術演化趨勢，目前冰箱的創新發展，在結構上著重於非對稱性空間(S8)與多系統的介面(I14, I15)，在功能與外觀上著重於方便性(I22)與簡約設計(I27)，在操作上則著重於協調性(T32)與智慧回饋(I28)。

除了家用冰箱創新的研究之外，其他研究也廣泛地運用 TRIZ 技術系統演化趨勢於不同類型產品與服務的創新。Chiang, Yi, & Chang (2013)結合 Kano 模型與 TRIZ 演化趨勢，以專家意見為資料來源，進行電子商務服務品質的改善；Ishi & De Carvalho (2015)則以光纖配線箱(optical fiber distribution box)為對象，運用 TRIZ 演化趨勢工具，同樣以專家意見為資料來源，進行創新產品的發想，並取得 42 個可能的創新想法。Sengupta, Kim, & Kim (2018) 結合 TRIZ 演化趨勢與 Bass 模型，以現有的技術報告與市場調查資料為基礎，探討智能手環(fitness trackers)的未來產品創新與市場採用階段。然而，目前尚未有研究運用 TRIZ 演化趨勢工具，特別針對家用冰箱進行創新發想，僅有的少數文獻則是探討一般性家電產品(household appliance)的發展趨勢(Crotti, Ghitti, Regazzoni, & Rizzi, 2007; Baur, Muenzberg, & Lindemann, 2017)。

表 1. 空間類別的演化趨勢

項目	演化趨勢
S1 智慧材料	被動材料 → 單向適應材料 → 雙向適應材料 → 全向適應材料
S2 空間分割	單一固體 → 中空結構 → 多孔結構 → 毛細孔結構 → 多孔結構+有效元素
S3 表面分割	光滑表面 → 肋狀表面 → 立體粗糙面 → 作用孔面
S4 物件分割	單一固體 → 分割固體 → 粒狀固體 → 液體 → 泡沫/氣霧 → 氣體 → 電漿 → 能場 → 真空
S5 從巨觀進化到微觀	Macro→Milli→Micro→Nano→Pico→Femto
S6 網狀纖維	均質平面架構 → 二維網狀架構 → 立體纖維 → 添加作用元素
S7 減少密度	金屬 → 塑膠 → 氣體
S8 增加非對稱性	對稱系統 → 線性非對稱 → 平面非對稱 → 匹配非對稱
S9 打破邊界	多重邊界 → 少數邊界 → 無邊界
S10 幾何進化(線性)	點 → 一維線性 → 二維平面 → 三維表面
S11 幾何進化(立體)	平面結構 → 二維結構 → 軸對稱結構 → 三維結構
S12 向下縮合	非結構化 → 二階結構 → 三階結構 → 遞迴架構
S13 動態性	不動系統 → 連結系統 → 完全彈性系統 → 液態/氣態系統 → 能源基系統

資料來源：整理自 Mann (2002)

表 2. 介面類別的演化趨勢

項目	演化趨勢
I14 單-雙-多(同質性)	單系統 → 雙系統 → 三系統 → 多系統
I15 單-雙-多(變異性)	單系統 → 雙系統 → 三系統 → 多系統
I16 單-雙-多(增加差異)	相似組件 → 變異組件 → 含修正組件 → 多系統
I17 向上整合	非結構化 → 與較高層結構結合 → 完全與較高層結構整合
I18 減少受迫阻尼震盪	過阻尼 → 來回震盪 → 無震盪+有效控制
I19 增加感官的使用	1 個感官 →2 個感官 →3 個感官 →4 個感官 →5 個感官
I20 增加顏色的使用	單色或無色 → 雙色 → 使用可見光譜色 → 全彩
I21 增加透明	不透明 → 部份透明 → 全部透明 → 可動透明組件

I22 顧客採購所關注的焦點	表現 → 可靠 → 方便 → 價格
I23 市場進化	商品 → 產品 → 服務 → 體驗 → 傳授/轉換
I24 設計考量	單點設計最佳化 → 雙點設計最佳化 → 不連續操作多點設計最佳化 → 持續設計再最佳化
I25 自由度	1 自由度 →2 自由度 →3 自由度 →4 自由度 →5 自由度 →6 自由度
I26 打破邊界	多重邊界 → 少數邊界 → 無邊界
I27 簡約設計	複雜系統 → 消除非關鍵組件 → 消除非關鍵次組件 → 簡約後系統
I28 控制度	直接控制 → 中介作動 → 回饋 → 智慧回饋
I29 減少人為參與	人力 → 人力+工具 → 人力+動力工具 → 人力+半自動工具 → 人力+自動工具 → 自動化工具
I30 設計方法	試誤法 → 穩定狀態設計 → 考慮暫時效應 → 考慮磨耗效果 → 考慮耦合效果 → 防呆設計
I31 減少能源轉換	三次能源轉換 → 二次能源轉換 → 一次能源轉換 → 零次能源轉換

資料來源：整理自 Mann (2002)

表 3. 時間類別的演化趨勢

項目	演化趨勢
T32 動作協調	不協調動作 → 部份協調動作 → 完全協調動作 → 間隔時不同動作
T33 節奏協調	持續動作 → 週期動作 → 共振/共鳴 → 行波
T34 非線性	線性系統 → 部份非線性 → 完全非線性系統
T35 單-雙-多(同質性)	單系統 → 雙系統 → 三系統 → 多系統
T36 單-雙-多(變異性)	單系統 → 雙系統 → 三系統 → 多系統
T37 從巨觀進化到微觀	Macro→Milli→Micro→Nano→Pico→Femto

資料來源：整理自 Mann (2002)

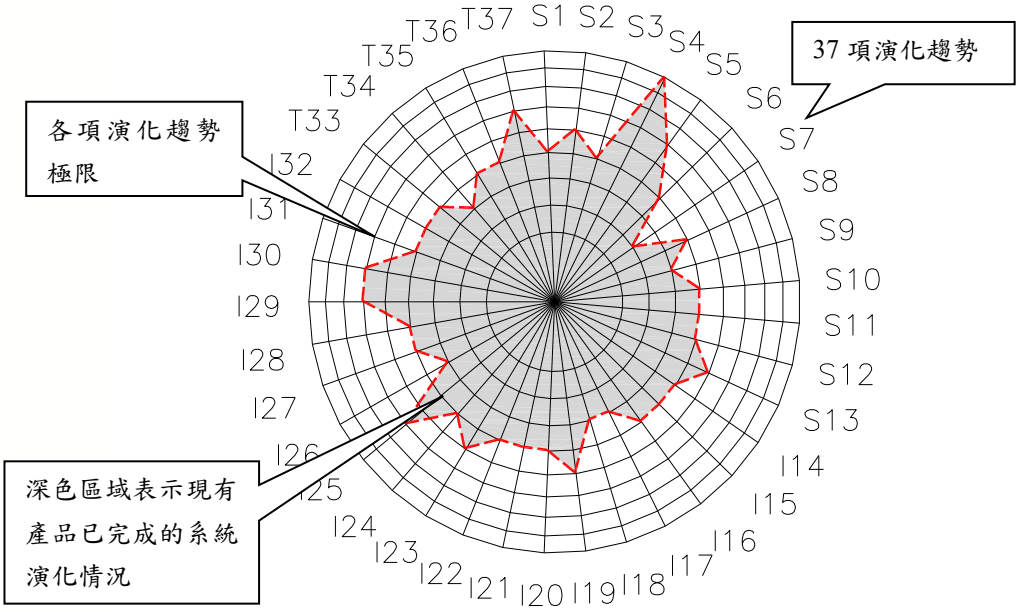

圖 1. 37 項技術演化潛力雷達圖

資料來源：Mann (2007)

2.3 技術演化潛力雷達圖

技術系統演化模式和演化路徑提供設計人員瞭解各類技術系統演化情況，為設計人員在產品技術開發方向提供了理論依據，圖 1 為 D. Mann 37 項技術系統演化潛力雷達圖。圖 1 中 37 條射線表示該構件或系統在技術演化的演化模式，深色區域表示產品將沿演化路徑演化，最後將達到外圍虛線，外圍虛線即表示系統內的各演化已達該趨勢演化極限，離外圍虛線越遠者即表示此趨勢較有演化潛力，可能潛藏著較多發明創新機會，達極限表示系統內的此一趨勢將不再演化或已無演化必要，也可能表示此一趨勢將由另一全新或破壞式創新趨勢取代。

3. 研究方法

3.1 研究方法及步驟

本研究的核心理論是藉由 37 項演化趨勢，可以探討冰箱各項功能上演變與趨勢之間的關係。首先，本研究廣泛進行冰箱功能資料蒐集，再進行 TRIZ 演化等級判斷，接著繪出功能演化雷達圖，再依此項進行演化趨勢分析，得知現階段冰箱功能發展現況及極限，依據此結果，再去推想冰箱未來發展方向。本論文研究方法及步驟如圖 2 所示。

參考先前的研究經驗(Chiang, Yi, & Chang, 2013; Ishi & De Carvalho, 2015)，本研究尋求專家意見作為衡量評估的基礎，故邀請 5 位家用冰箱領域的企業資深專家，曾歷練於研發、行銷與生產部門，皆擁有 20 年以上產業經驗。本研究提供 5 位專家所蒐集的冰箱功能資料，並附上 37 項演化趨勢的定義說明，以個別面訪的方式，由專家協助將冰箱功能資料對應到適當的 TRIZ 演化趨勢，再進行演化等級的判斷。在此過程中，5 位專家是以匿名方式參與研究，其中若有 3 位以上的專家意見一致，則確認該項 TRIZ 演化等級達成共識，並據此繪製演化雷達圖，反之，若該項 TRIZ 演化等級僅有 2 位或更少的專家意見一致，則會提供其他匿名專家的書面意見，進行第二次的面訪，透過專家書面意見交流來達成共識。

3.2 冰箱產品功能蒐集

本研究主要以冰箱功能作為研究目標，收集資料範圍設定國內冰箱業界具有代表性公司分別為 Panasonic 國際牌、HITACHI 日立、KOLIN 歌林、SAMPO 聲寶、SANYO 台灣三洋、TATUNG 大同作為研究對象，收集五家公司歷年廣告文宣資料，自民國 84 年到民國 105 年間之家用冰箱產品功能相關資料，如圖 3 所示，總計有 90 本廣告文宣、288 件功能資料，內容部份有重複，現有功能並非每年全部發展成新功能，因此，在彙整廣告文宣中的主打特殊功能、冰箱基本規格之後，發現每三年期間，冰箱功能會改變一次，故將以三年為週期進行統計。

由於本研究以冰箱功能作為研究目標，為了瞭解使用者對目前冰箱購買動機、使用狀況，參考漂亮居家雜誌的問卷調查，「安全」、「節能」、「性能」、「設計」、「服務」是消費者在購買冰箱的重要考量因素，其中「安全」、「節能」已成為基本配備，「性能」、「設計」成為讓消費者願意購買的關鍵因素，對於性能好、設計佳的冰箱，會讓消費者提升預算購買。所謂「性能」是指更貼近使用習慣的冰箱，提升使用的「方便性」，以及透過「溫度控制」能鎖住食物的原味；「設計」方面是指冰箱「外觀設計」以及內部「空間設計」。故本研究將蒐集冰箱功能內容資料，依「方便」、「空間設計」、「溫度控制」、「外觀設計」分類區分，再細分個別相關之功能共 14 項，探討國內冰箱產品創新功能演變過程，如表 4 所示。

4. 研究分析與結果

4.1 冰箱功能演化參數與等級判斷

本研究根據表 4 中的各項功能演化說明，分別就「方便性」、「空間設計」、「溫度控制」、「外觀設計」的分類，對照 37 項演化趨勢，找出符合的演化趨勢參數，並判斷演化等級。以「方便性」的製冰功能為例，以往製冰時，消費者需要將製冰盒拉出來倒入液體，在以平放方式放入冷凍室，當液體結成固體，在手動完成製冰，製冰數量有限，沒辦法儲存冰塊，如果夏季需要大量冰塊時，無法滿足消費者；演變成扭轉式製冰盒，還是需要將製冰盒拉出，手動倒入液體，但差別在於製冰盒採用扭轉式設計，當液體結成固體，輕輕扭轉，冰塊自動脫落至儲冰盒中，輕鬆好用；演變成製冰動作時無需人為操作，只需把冷藏室水箱裝滿，水箱會自動運轉至冷凍製冰，再由智慧型感溫器感測製冰完成，讓冰塊源源不絕，如圖 4 所示。

圖 2. 研究步驟

圖 3. 冰箱廣告文宣與基本規格之資料範例
資料來源：台灣 National 商品文宣與型錄（2003）

表 4. 消費者選購冰箱之關鍵因素及相關功能

關鍵因素	功能	功能演化說明
方便性	1. 製冰功能	製冰盒 → 扭轉式製冰盒 → 自動偵測製冰系統
	2. 燈光照明	無燈光照明 → 冷藏有燈光 → 冷凍與冷藏皆有燈光
	3. 除臭功能	使用者外購除臭裝置 → 冰箱內建除臭裝置 → 急速除臭按鍵
	4. 關門警示	冰箱門沒關好 → 發出警示聲 → 發出警示聲與顯示警示燈
	5. 電動抽屜／門	手動拉門 → 輕觸電動門
空間設計	6. 內部空間分層存放	單層開放式 → 單層密閉隔間 → 單層密閉多格
	7. 冷藏室與冷凍室位置	冷凍在上，冷藏在下 → 冷藏室在上，冷凍室在下
	8. 冰箱寬度	冰箱強調超大容量 → 寬度變窄，廚房空間寬敞
溫度控制	9. 溫度控制界面	庫內調整溫度 → 庫外調整溫度 → 自動調節溫度
	10. 冰箱氣流	直吹氣流 → 廣角氣流 →3D 氣流
	11. 急速冷凍室	無要求冷凍速度 → 短時間內冷凍食物 → 熱料理急速冷凍
	12. 微凍結室	冷凍食材需解凍料理 → 食材取出即可料理
外觀設計	13. 外觀顏色	單色淺色系 → 雙色系 → 顏色選擇豐富
	14. 庫外液晶顯示面板	庫外溫控面板 → 多功能面板

圖 4. 製冰功能的演化過程

其中自動給水製冰系統，將給水、製冰、離冰的三項步驟，形成連續性、自動化的操作流程，可對應至 S13「動態性」第三階段（完全彈性系統），以及 I29「減少人為參與」第五階段（人力＋自動工具），此系統也讓使用者更佳方便製作冰塊，可對應至 I22「顧客採購所關注的焦點」第三階段（方便），再者，從 I28「控制度」而言，當水箱沒水時，指示燈會亮起，告知使用者要添加冷開水，讓製冰功能保持循環，達到第三階段（回饋），最後，在自動偵測製冰過程中，將冷藏室水箱的水抽至冷凍室製冰盒內，開始製冰，當製冰完成後，蓄冰盒有感測器檢測冰塊儲存量是否足夠，不足時製冰盒會自動扭轉，將剛製成的冰塊倒入蓄冰盒，透過自動製冰、自動離冰兩個系統，彼此交互感測，讓使用者隨時都有冰塊享用，可對應於 T32「動作協調」第三階段（完全協調動作），以及 T33「節奏協調」第三階段（共振/共鳴），如表 5 所示。其他的冰箱功能演化，也基於所蒐集冰箱功能內容資料，根據 5 位專家意見共識，依循上述的方法進行判斷，彙整如表 5 至表 8 所示。

表 5. 「方便性」之演化參數與等級判斷

關鍵因素	功能	判斷參數等級說明	演化趨勢參數	演化等級
方便性	製冰功能	自動給水製冰系統	動態性	S13-3
			減少人為參與	I29-5
		自動製冰具便利性	顧客採購所關注的焦點	I22-3
		水箱補水訊息回饋	控制度	I28-3
		自動製冰、自動離冰	動作協調	T32-3
			節奏協調	T33-3
	燈光照明	冷凍與冷藏皆有燈光	打破邊界	S9-2
			單-雙-多(同質性)	I14-2
		光線可部份穿透	增加透明	I21-2
		燈光照明具穩定性	顧客採購所關注的焦點	I22-2
	除臭功能	內建除臭裝置	顧客採購所關注的焦點	I22-2
		急速除臭按鍵	控制度	I28-2
	關門警示	提醒聲與警示燈	增加感官的使用	I19-2
		警示具提醒效果	顧客採購所關注的焦點	I22-1
		聲音與燈號雙重設計	設計考量	I24-2
	電動抽屜／門	輕觸方式開關	顧客採購所關注的焦點	I22-3
			減少人為參與	I29-5
			控制度	I28-2

表 6. 「空間設計」之演化參數與等級判斷

關鍵因素	功能	判斷參數等級說明	演化趨勢參數	演化等級
空間設計	空間分層存放	單層密閉多格	單-雙-多(同質性)	I14-4
		方便整理取用	顧客採購所關注的焦點	I22-3
	冷藏室與冷凍室位置	冷藏室在上，冷凍室在下	自由度	I25-1
		調整冷藏與冷凍室位置	打破邊界	I26-2
		依使用者使用頻率調整	設計方法	I30-2
	冰箱寬度	寬度變窄，廚房空間寬敞	顧客採購所關注的焦點	I22-3

表 7. 「溫度控制」之演化參數與等級判斷

關鍵因素	功能	判斷參數等級說明	演化趨勢參數	演化等級
溫度控制	溫度控制界面	無需調整溫度	顧客採購所關注的焦點	I22-3
		多點感應器設置	設計考量	I24-3
		既定溫控調節模式	自由度	I25-1
		自動偵測調節溫度	控制度	I28-3
			減少人為參與	I29-5
		達到穩定設計狀態	設計方法	I30-2
	冰箱氣流	3D 氣流，冷度均勻分布	顧客採購所關注的焦點	I22-2
		由上、左、右三方向吹動	幾何進化(立體)	S11-2
		達到穩定設計狀態	設計方法	I30-2
	急速冷凍室	熱料理急速冷凍	顧客採購所關注的焦點	I22-3
	微凍結室	冷凍室與微凍結室	單-雙-多(同質性)	I14-2

表 8. 「外觀設計」之演化參數與等級判斷

關鍵因素	功能	判斷參數等級說明	演化趨勢參數	演化等級
外觀設計	外觀顏色	金屬鏡面，顏色選擇豐富	增加顏色的使用	I20-3
	庫外液晶顯示面板	多功能面板	單-雙-多(變異性)	I15-4
		面板熄燈即隱藏	增加透明	I21-1
		簡化面板功能	顧客採購所關注的焦點	I22-3
			簡約設計	I27-2

4.2 繪製冰箱功能演化雷達圖

本研究蒐集冰箱功能內容資料，依「方便性」、「空間設計」、「溫度控制」、「外觀設計」分類區分，進行演化趨勢參數辨識及演化等級判斷，如表 5 至表 8 所示。在各項資料表中，若該項功能僅對應一項功能演化特徵值，則將此功能直接歸類至該項演化趨勢參數等級，但若一項演化趨勢參數對應超過一項以上的功能，則採用平均數法進行計算，其平均值即為此項演化趨勢參數等級。最後透過 Microsoft Excel，繪製對應於「方便」、「空間設計」、「溫度控制」、「外觀設計」的演化雷達圖，如圖 5 至圖 8 所示，並在圖中呈現出目前演化狀態與演化極限，以便發掘具有產品發展潛力的參數，進行冰箱未來趨勢的創新產品構思。

5. 創新產品構思

5.1「方便性」創新構思

(1) 燈光照明功能

S9「打破邊界」目前處於第二階段（少數邊界），預測往第三階段（無邊界）邁進，I14「單-雙-多(同質性)」目前處於第二階段（雙系統），預測往第四階段（多系統）邁進，國人每天使用手機超兩個小時已有 80%以上，冰箱將會往智慧型家電邁進，須結合「通訊功能」、「攝影機」、「傳感器」，冰箱跟使用者須雙向互動，使用者可輕鬆管理自己的冰箱。I21「增加透明」目前處於第二階段（部份透明），預測往第三階段（全部透明）邁進，透過通訊軟體來監控冰箱內部食物狀況，冰箱燈光須完全穿過，無任何限制，要讓使用者可透過手機清楚看到冰箱內部狀況。使用者可透過通訊軟體來監控冰箱內部狀況，這時考慮到不同操作模式(開門、關門…等)，冰箱照明須在透明、部分透明及不透明三者間改變，冰箱即使門關起，使用者也可得知冰箱內部狀況，如圖 9 所示。

(2) 關門警示功能

I22「顧客採購所關注」目前處於第一階段（表現），預測往第二階段（可靠）邁進，I19「增加感官的使用」目前處於第二階段（2 個感官），預測往第三階段（3 個感官）邁進，使用者一時疏忽常忘了關冰箱門，目前設計僅有警示燈與提醒聲來告知使用者，可在冰箱內部多點操作點設置溫度感應器，能清楚偵測到溫度變化，當溫度異常升高時，可透過通訊軟體主動傳送訊息給使用者，告知冰箱哪區域未關好，讓使用者更信賴關門警示功能，如圖 10 所示。

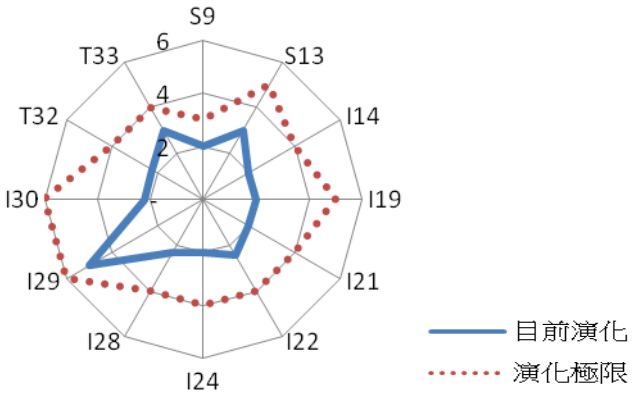

圖 5. 「方便性」功能演化雷達圖

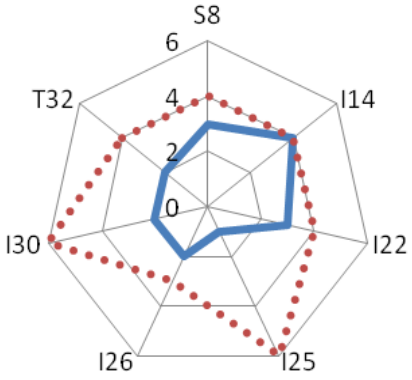

圖 6. 「空間設計」功能演化雷達圖

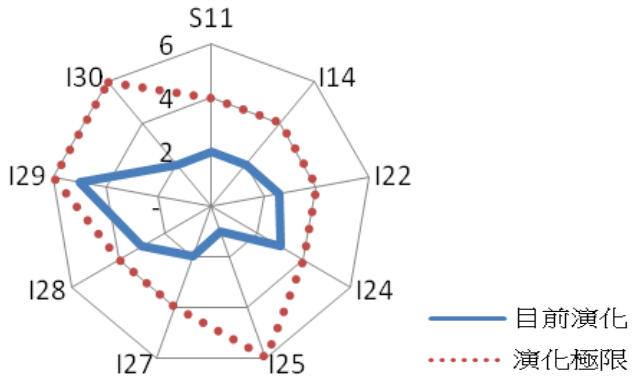

圖 7. 「溫度控制」功能演化雷達圖

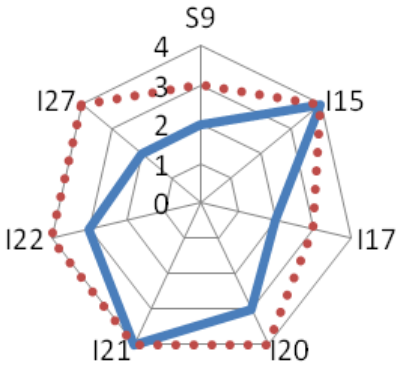

圖 8. 「外觀設計」功能演化雷達圖

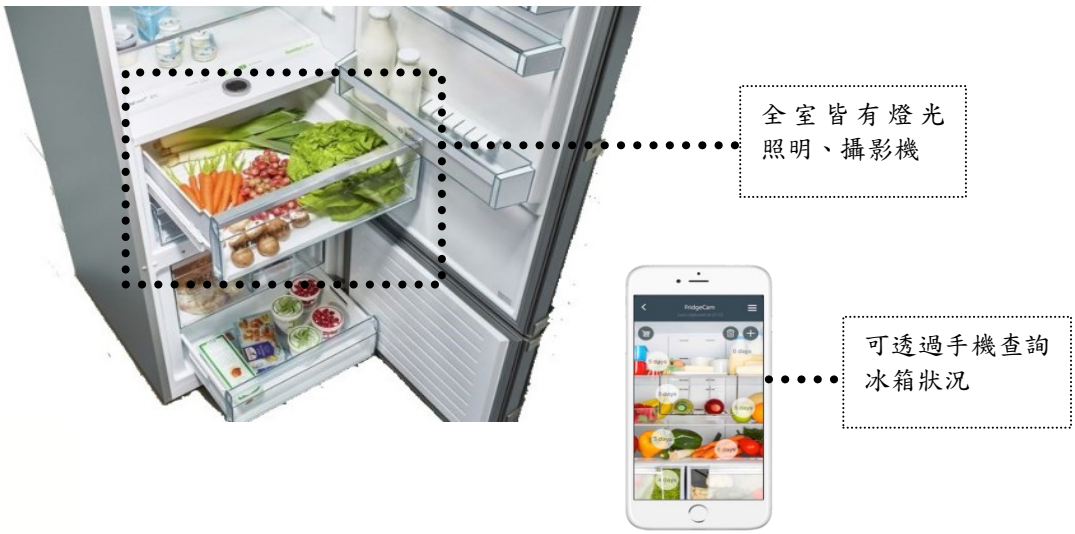

圖 9. 「燈光照明」功能創新設計

資料來源：Bosch Refrigerator (2021)、Sande (2017)

圖 10. 「關門警示」功能創新設計
資料來源：Bosch Refrigerator (2021)、Sande (2017)

5.2「空間設計」創新構思

(1) 冷藏室與冷凍室位置

I25「自由度」處於第一階段（1 自由度），預測往第三階段（3 自由度）邁進，I26「打破邊界」目前處於第二階段（少數邊界），預測往第三階段（無邊界）邁進，國人居住空間小，又有過年習俗，因此冰箱須具備彈性空間設計，冷凍室、冷藏室、蔬果室自由切換，不需要任何限制，不須再為保存食物空間不足傷透腦筋，增加使用者方便。I30「設計方法」目前處於第二階段（穩定狀態設計），預測往第三階段（考慮暫時效果）邁進，考慮不同的暫時效果操作狀況，不需要任何限制，冷凍、冷藏、蔬果室可自由切換，如圖 11 所示。

5.3「溫度控制」創新構思

(1) 溫度控制界面

I25「自由度」目前處於第一階段（1 自由度），預測往第二階段（2 自由度）邁進，I30「設計方法」目前處於第二階段（穩定狀態設計），預測往第三階段（考慮暫時效應）邁進，挖掘潛在用戶的痛點，例如：熱愛烘培的族群，需要隨時掌握溫度，冰箱的溫控界面可直接調整各區域的溫度，也可以透過手機通訊軟體來調整溫度控制，讓使用者隨時掌握某區塊隔層溫度，增添使用者使用上便利性。I28「控制度」目前處於第三階段（回饋），預測往第四階段（智慧回饋）邁進，讓使用者可以自由設定區域溫度，隨時掌握某區塊隔層溫度，且自動對使用者對發訊者傳遞告知此溫度已維持時間，增添使用者使用上便利性，如圖 12 所示。

5.4「外觀設計」創新構思

(1) 外觀顏色、庫外液晶顯示面板功能

I21「增加透明」目前處於第一階段（不透明），預測往第二階段（部份透明）邁進，掌握未來科技功能，引進「變色玻璃」將不透明的玻璃變成透明，無須打開冰箱就可知道冰箱內部食物狀況，可以減少能源損耗。另外，I20「增加顏色」目前處於第三階段（使用可見光譜色），預測往第四階段（全彩）邁進，透過智慧玻璃的運用，可隨著裝潢而有所變化，顏色選擇豐富，讓消費者依照自己喜好選擇。I27「簡約設計」目前處於第二階段（消除非關鍵組件），預測往第三階段（消除非關鍵次組件）邁進，可同時引進「手勢感應器」使用者只要揮動雙手，就可以將不透明的玻璃變成透明，如圖 13 所示。

圖 11. 「彈性空間」功能創新設計
資料來源：Bosch Refrigerator (2021)

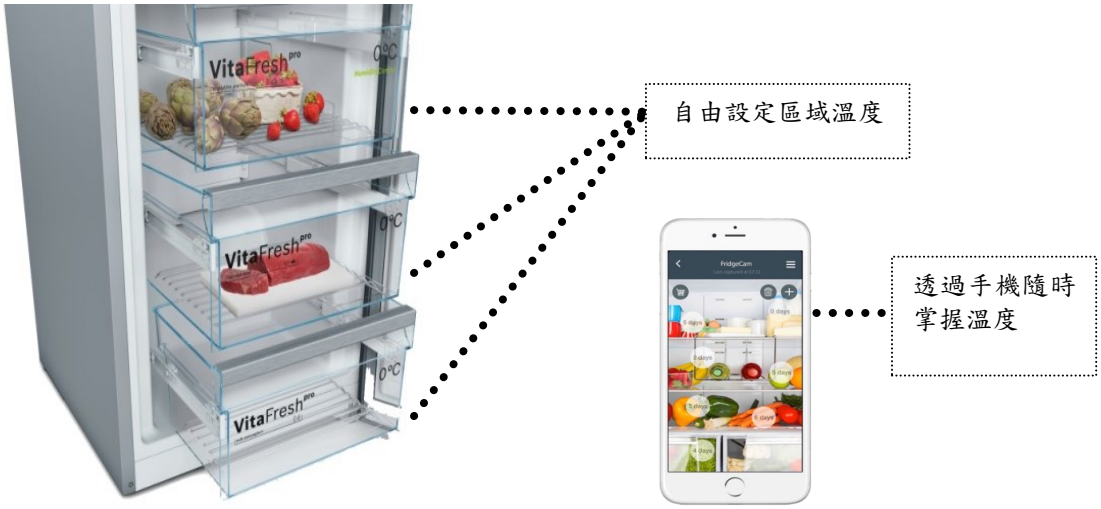

圖 12. 「溫度控制」功能創新設計
資料來源：Bosch Refrigerator (2021)、Sande (2017)

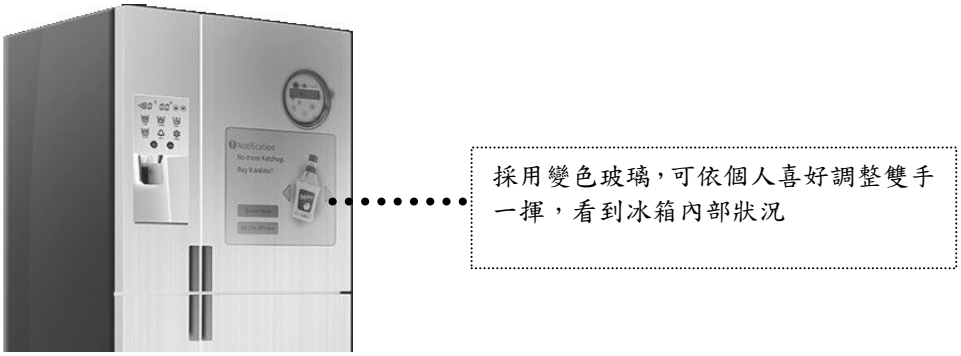

圖 13. 「外觀設計」功能創新設計
資料來源：Dreamstime (2021)

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BIOGRAPHY

Wen-Chun Tsai is currently an Assistant Professor in the Department of Business Administration at Chung Yuan Christian University in Taiwan (ROC). He received his MS in Electrical Engineering from Stanford University (USA) and PhD in Management of Technology from National Chengchi University, Taiwan (ROC), respectively. His research interests are technology management, product and service innovation and business model design.

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