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Research Article

TRIZ approach to the relevant problem for the transport of assay tubes: A case study on family health centers in Amasya

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ABSTRACT

Amasya is a province of Turkey, situated on the Yeşil River in the Black Sea Region to the north of the country. In Family Health Centers (FHC), in the province of Amasya, a different method is applied for blood tests according to hospitals. Assay tubes are sent to the central laboratory outside the FHC or to the hospital laboratory in the city center by road transportations. This method brings time loss and financial burden. Theory of Innovative Problem Solving (TRIZ)-based solution proposal is presented as an alternative approach for the transport of assay tubes by taking into consideration the family health centers in Amasya. The problem was transformed into a TRIZ problem and solutions were produced using appropriate principles. Drone usage is proposed as a solution. If drone usage is preferred over vehicle use, it has been observed that it provides 93% financial and time savings. Today, the great impact of the COVID-19 pandemic on global healthcare systems has led to seeking new tools and methods to overcome the crisis. The use of drone technology has become even more important in order to provide fast and wide-ranging service, especially in the period of medical crisis, by reducing contact from person to person.

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INTRODUCTION

Health services and delivery are of great importance for improving the quality of life and for the continuity of human life. Therefore, the quality of health services is known as a sign of the socio-economic development level of world countries [1]. In the health sector, the use of technology is of great importance to serve patients more comprehensively and faster. To provide better laboratory facilities, innovative applications should be applied in the solutions to transportation and access problems. In particular, the absence of diagnostic devices in every health center significantly restricts access to patients. For the tests that are deemed necessary in health screenings performed in FHCs, it is delivered to the central laboratories at a certain time of the day and the test cannot be taken again during the day.

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It is a limitation of the service provided to the patient and the physician that the test tubes can be taken only once a day in a short period of time with a blood donation time. The fact that this process can be carried out several times a day presents financial difficulties. The use of drones designed for different purposes for the transport process creates a situation of reduced manpower production and service, while at the same time offering an innovative solution to the problems. Nowadays, drones are used in search and rescue activities for people who are lost in high altitude areas, and from the delivery of vital foodstuffs to the use of pre-intervention observations in events such as fire, earthquake, flood, and forest fire [2-5]. In health services, especially in cases such as drowning and cardiac arrest requiring emergency assistance within seconds, it has been shown that assistance can be provided by drones as soon as possible [6,7]. Recently, studies on the transportation of medical samples using a drone are becoming widespread [8-12]. Amukele et al. [13] have reported the drones may be suitably used for transportation of laboratory specimens. They were also found not to affect the accuracy of the tests in routine clinical chemistry, hematology, and coagulation analyzes performed after drone transport of blood samples. However, the most important risk in the transport of blood samples by drones is the malfunction of the drones [14].

Although TRIZ is a well-known problem-solving method that is frequently encountered in engineering fields, there are only a few studies that use TRIZ to improve service quality in health care. In the study of Altuntaş and Yener, they aimed to provide the best service for patients in hospitals by using TRIZ methodology and SERVQUAL (method used to measure service quality) quality improvement methods to increase the quality of hospital services [15]. TRIZ has been used in many details from the hospital design to the clothing of the working personnel by using the statistical data they have created with the questionnaires conducted on all patients who come to the hospital since 2011.In the study conducted by Lin et al., they used TRIZ methodology to increase the quality of hospital services and patient satisfaction and provided the systematic solution of the problem with the matrix of contradictions. This study, which was conducted to reduce the complaints of the patients, provides an important reference for the people who provide health services [16]. In the study conducted by Gao et al., they used the TRIZ method to demonstrate the application of modern design methodology in medical equipment [17].

In this study, alternative methods that would speed up the delivery of samples taken from Family Health Centers (FHC) to research laboratories were investigated. At the same time, the new method that can be used was analyzed financially according to the method used.

THEORETICAL BACKGROUND

Theory of Innovative Problem Solving (TRIZ)

TRIZ, also known as the "Creative Problem Solving Theory, was developed by the Soviet scientist Genrich Saulovich Altshuller and his team working at the patent office, examining around 200.000 patents. Genrich Altshuller has worked on the innovative thinking of people and the development of this innovation in solving problems. Analyzing that innovation is a technological change, Altshuller found that 40.000 patents out of 200.000 patents have creative features. These creative patents prepared the theoretical structure of TRIZ and became the basis for TRIZ methodology. Over the next 40 years, the TRIZ method developed and nearly 2 million patents were examined. These creative patents prepared the theoretical structure of TRIZ and became the basis for TRIZ methodology. Over the next 40 years, the TRIZ method developed and nearly 2 million patents were examined [18-20].

Approximately 90-95% of the problems in TRIZ method are recurring problems. It was observed that while solving problems, it created problems in itself and this situation created contradictions. If there is no case of perfection, the problem and its solution are always contradictory. If there is action, the reaction must occur. In the TRIZ method, as a result of examining thousands of patents so far, 39 engineering parameters that form the basis of the inventions have been determined. The contradiction matrix consists of a total of 40 different creative principles placed in 1.521 cells by forming a 39x39 square matrix with 39 contradiction parameters. The rows indicate the actions in the system, i.e. the improving features, the columns indicate the reaction, i.e. the worsening features [20-22]. TRIZ, which was first used for the solution of problems in the field of mechanical and engineering, is now used in education, transportation, communication, etc. It has started to be used and recommended in many areas [23-26]. Altshuller also summarized 40 principles of invention from these patents, regarding to the contradiction matrix [20].

Defining the Problem

There are 20 FHCs where 50 family physicians work in the central district of Amasya Province, Turkey. The average number of test tubes collected from 20 FHCs (with expert opinion) was determined as 500 tubes such as biochemistry, hemogram, urine, coagulation, and sedimentation. The test tubes taken from FHCs every weekday and at a certain hour are transported to a central laboratory (Lab-2) in the Public Health Laboratory of the Provincial Directorate of Health for analysis. In the center of Amasya Province, there is also a laboratory (Lab-1) that provides a comprehensive service within Amasya University Sabuncuoğlu Şerefeddin Education and Research Hospital. Considering that two laboratories could serve, it was investigated which laboratory would be more productive according to the results obtained.

The distances of each FHC to the laboratories in the center have been determined separately and the distances are calculated in the shortest way and are tabulated in Table 1. The fact that test tubes can be taken only once a day in a short period of time with a blood donation time imposes limitations on the service provided. When the patient somehow misses the given time, he has to give the next day. The problem is the frequency of transporting test tubes to laboratories, i.e. time and transportation. It has been tried to calculate the transportation of the samples of the patients from the FHCs located in the center of Amasya Province to the nearest laboratories faster and how this process can be performed several times a day.

Use of the Contradictions Matrix

The problem has been transformed into TRIZ problem, worsening features were determined according to improving features and solutions have been produced by using the appropriate principles from 40 creative principles in the 39x39 contradictions matrix.

The fact that the carrier vehicle collects the test tubes at a certain time of the day and delivers them to the laboratory creates a time limitation. It is desirable that it be done several times a day, not once or twice. The fact that this process can be done in a short time and can be repeated several times a day is related to speed. The speed and durability of moving objects are expected to be improved to eliminate the limitations of the carrier vehicle by collecting all the test tubes at a certain time of the day and transporting them to the laboratory.

Contradiction-1

The feature that is expected to be developed "durability of moving object- 15": It is aimed to deliver the test tubes in a short time and the action time of the moving Object is the feature we expect to improve.

The worsening feature of its development "harmful factors acting on object-30": During the delivery of blood test tubes in a short time to be encountered during traffic density, road-related stopping, turning, refueling situations such as. The principles proposed in the contradictions matrix are given as 15, 22, 28 and 33.

Contradiction-2

The feature that is expected to be improved "speed – 9": It is aimed to deliver the test tubes quickly. A faster vehicle will be needed to ensure that the blood tubes can be reached in a short time.

The worsening feature of its development "energy spent by moving object – 19": It is undesirable that the energy consumed by the object will be too much for the rapid delivery of test tubes. The principles proposed in the contradictions matrix are given as 8, 15, 35 and 38.

Solution Proposals

To solve the problem, the principles 8, 15, 22, 28 and 35 were chosen from the solution proposals presented by the matrix of contradictions. Let us examine the solution proposals using these principles.

8-Counterweight

15-Dynamicity

Table 1. Determination of FHC-Laboratory distance as shortest

No	FHC	FHCs Geographical Coordinate (latitude- longitude)	Lab.	Labs Geographical Coordinate (latitude- longitude)	Distance (m)
1	1st	40°39'03.55"N 35°49'25.99"E	Lab-2	40°39'24.43"N 35°50'19.56"E	1.656
2	2nd	40°38'58.57"N 35°48'41.04"E	Lab-2	40°39'24.43"N 35°50'19.56"E	1.076
3	3rd	40°39'16.93"N 35°48'31.41"E	Lab-2	40°39'24.43"N 35°50'19.56"E	476
4	4th	40°39'14.88"N 35°48'12.67"E	Lab-2	40°39'24.43"N 35°50'19.56"E	636
5	5th	40°39'29.30"N 35°50'17.67"E	Lab-1	40°39'41.74"N 35°50'47.64"E	885
6	6th	40°39'57.89"N 35°50'11.18"E	Lab-1	40°39'41.74"N 35°50'47.64"E	1.060
7	7th	40°38'55.81"N 35°49'40.20"E	Lab-2	40°39'24.43"N 35°50'19.56"E	2.053
8	8th	40°38'57.24"N 35°49'42.98"E	Lab-2	40°39'24.43"N 35°50'19.56"E	2.005
9	9th	40°40'02.01"N 35°50'50.59"E	Lab-1	40°39'41.74"N 35°50'47.64"E	708
10	10th	40°39'31.99"N 35°48'17.26"E	Lab-2	40°39'24.43"N 35°50'19.56"E	0
11	11th	40°38'39.22"N 35°48'21.75"E	Lab-2	40°39'24.43"N 35°50'19.56"E	1.636
12	AYDINCA	40°39'40.78"N 35°49'58.68"E	Lab-1	40°39'41.74"N 35°50'47.64"E	28.478
13	DOĞANTEPE	40°35'43.05"N 35°36'14.03"E	Lab-2	40°39'24.43"N 35°50'19.56"E	19.636
14	EZİNEPAZAR	40°34'06.00"N 36°02'44.63"E	Lab-1	40°39'41.74"N 35°50'47.64"E	22.872
15	İPEKKÖY	40°36'24.81"N 35°48'45.40"E	Lab-2	40°39'24.43"N 35°50'19.56"E	5.944
16	KAYABAŞI	40°34'26.54"N 35°45'23.96"E	Lab-2	40°39'24.43"N 35°50'19.56"E	11.765
17	KIZILCA	40°30'49.78"N 35°46'01.96"E	Lab-2	40°39'24.43"N 35°50'19.56"E	17.237
18	UYGUR	40°33'31.56"N 35°59'49.72"E	Lab-1	40°39'41.74"N 35°50'47.64"E	18.614
19	YEŞİL YENİCE	40°41'07.21"N 35°57'24.17"E	Lab-1	40°39'41.74"N 35°50'47.64"E	11.124
20	ZİYARET	40°41'03.28"N 35°52'08.96"E	Lab-1	40°39'41.74"N 35°50'47.64"E	3.358

22-Convert harm into benefit
28-Replacement of a mechanical system
35-Transformation properties

According to principle 8, it is said to balance the weight of the transported objects with an aerodynamic or hydrodynamic force affected by the platform on which it is located. That is, it is proposed that a different force must be applied to balance the force. This force can be obtained from the propeller system which creates a thrust force in the upward direction.

According to Principle 15, it is said that the platform where the object is located should be changed. One of the main reasons for the loss of time is the fact that the road route of the carrier vehicle remains the same, the vehicle cannot exceed the motorway speed limit and there are stops, turning, refueling, etc. from the roads. As the speed does not remain constant for reasons such as access to the laboratory increases the loss of time. Said platform means that the path where the vehicle touches the ground needs to be changed, i.e. that there should be an environment with the least frictional force. Our suggestion for this is to prefer the airway instead of the road.

According to Principle 15, if the object is stationary, move it and make it replaceable. It is suggested that by changing our vehicle which is actually moving but moving in one route, we can be made to move in different dimensions.

According to Principle 35, It is said that physical condition should change and the physical appearance of the carrier must be changed.

When these principles are taken into consideration, it has been found that our option for the transportation of solution proposals should be a vehicle which is balanced with an aerodynamic force, that is, has a propulsion system, can move in many dimensions and can be used in air transportation. It is concluded that the aircraft with the specified characteristics could be a drone.

RESULTS AND DISCUSSION

Some of the industrial drones developed for the transportation system where speed, range and load are important are given in Table 2. Some drones do not use range, but they can also fly up to flight time with encoding and GPS data.

A carrying box of 30x22x24 cm^3 is required to accommodate 50 test tubes. This box weighs 2 kg when it is empty and comes with 3 kg with tubes.

The A-brand drone with a 36 minutes flight time can easily bring a 3 kg load (approximately 300 blood test tubes) to FHCs with a flight time of less than 36 minutes. In places with more than 36 minutes of flight distance, the battery will be removed with the common point to be determined and replaced with a full spare battery.

The closest FHC-Lab. distance for using the A-brand drone for the distance is given in Table 3. According to this chart, it is shown how many minutes can be reached from FHC to Lab with 40 km/h in horizontal and 12 km/h in vertical (take-off) with A brand drone.

The power of a 6S cell 30A battery is determined as 6 x 3,7V = 22,2V and the current of 30A is calculated as P = (22,2V) x (30A) = 666W. The drone, which is connected to a 2 6S cell 30A battery, has 22,2V value of a brushless motor with BR4114 model and has a thrust of 23,8N (~ 2,43kg) and draws current in 1 hour. Flight time can be calculated considering 17 A. Accordingly, any drone with 5 brushless motors can handle 5x23,8N = 119N (~ 12,5kg) load, and the weight of technical parts (~ 7kg) of the drone can be increased up to 50N (~ 5kg). It can be said that it can handle a load easily. Flight time also;

$$\text{flight time} = \frac{2x30A}{5x17A} x60min.=42,35 \text{ min.} \quad (1)$$

When any designed drone is used for FHC-Lab flight time, how much electric power will be consumed and the current (October-2019) Turkish Lira equivalent for the flight between Ipekköy FHC and Lab-2 are calculated. It is found as 0,206 kWh (The power of a 2 6S cell 30A battery is 1.332W and the energy it will spend between Ipekköy FHC-Lab-2 W = 1.332W x 0,1551h = 206,6Wh).

As a result, the cost for the distance between Ipeköy FHC-Lab-2 is 0,2066 kWh x 0,11 Euro = 0,023 Euro. The monetary value of each FHC-Lab distance in Amasya Province is calculated in Table 4.The total cost of electricity spent from all FHCs to Labs is 0,62 Euro. If, it is calculated that daily departures and arrivals are made once a day and, the total amount spent in a year is 4,06 TL x 2 x 250 days =310 Euro.

Table 2. Industrial Drones

	A	B	C	D
Load to Carry (kg)	3	2	6	3
Flight time (min.)	36	41	16	20
Control Range (m)	3.000-9.000	3.000-9.000	3.500	3.500
Horizontal Speed (km/h)	40	40	18	18
Vertical Speed (km/h)	12	12	8	10
Wind Resistance (km/h)	36	36	3	3

Table 3. Distances of FHCs to Laboratories (min.)

No	FHC	Lab.	Total Flight Time (s)			
			A	B	C	D
1	1st	Lab-2	158,7	158,7	342,7	338,56
2	2nd	Lab-2	106,5	106,5	226,7	222,56
3	3rd	Lab-2	52,5	52,5	106,7	102,56
4	4th	Lab-2	66,9	66,9	138,7	134,56
5	5th	Lab-1	93,3	93,3	193,25	187,4
6	6th	Lab-1	105,9	105,9	224,5	220
7	7th	Lab-2	193,8	193,8	421,35	417,48
8	8th	Lab-2	189,9	189,9	412,25	408,2
9	9th	Lab-1	73,2	73,2	152,7	148,56
10	10th	Lab-2	0	0	0	0
11	11th	Lab-2	156,9	156,9	338,7	334,56
12	AYDINCA	Lab-1	2.852,4	2.852,4	6.040,1	5.916,08
13	DOĞANTEPE	Lab-2	1.963,8	1.963,8	4.161,2	4.076,96
14	EZİNEPAZAR	Lab-1	2.325,6	2.325,6	4.892,4	4.777,92
15	İPEKKÖY	Lab-2	554,7	554,7	1.212,3	1.203,84
16	KAYABAŞI	Lab-2	1.282,5	1.282,5	2.619,25	2.523,4
17	KIZILCA	Lab-2	1.685,1	1.685,1	3.606,65	3.549,32
18	UYGUR	Lab-1	1.930,2	1.930,2	4.026,3	3.917,04
19	YEŞİL YENİCE	Lab-1	1.195,2	1.195,2	2.455,8	2.372,64
20	ZİYARET	Lab-1	312,3	312,3	683,6	679,28

Table 4. The prices of energy spent on flights between FHC-Lab

No	FHC	FCH to Lab.(h)	Work (kWh)	Euro (Euro/km)
1	1st	0,0441	0,058719	0,006
2	2nd	0,0296	0,039405	0,005
3	3rd	0,0146	0,019425	0,002
4	4th	0,0186	0,024753	0,003
5	5th	0,0259	0,034521	0,003
6	6th	0,0294	0,039183	0,005
7	7th	0,0538	0,071706	0,008
8	8th	0,0528	0,070263	0,008
9	9th	0,0203	0,027084	0,003
10	10th	0	0	0,000
11	11th	0,0436	0,058053	0,006
12	AYDINCA	0,7923	1,055388	0,115
13	DOĞANTEPE	0,5455	0,726606	0,079
14	EZİNEPAZAR	0,6460	0,860472	0,093
15	İPEKKÖY	0,1551	0,206571	0,023
16	KAYABAŞI	0,3563	0,474525	0,052
17	KIZILCA	0,4681	0,623487	0,067
18	UYGUR	0,5362	0,714174	0,078
19	YEŞİL YENİCE	0,3320	0,442224	0,047
20	ZİYARET	0,0868	0,115551	0,012
			Total	0,620

The total distance of A-brand drone from FHC to Labs is 151.217 m and the energy consumed is 0,62 Euro. According to these data, the energy consumed by A brand drone per kilometer would be 0,0041 Euro (0,62 Euro / 151.217 km). The carrier vehicle with 1.6 105 HP MULTIJET Motor consumes 6,4 liters of fuel at 100 km in the city. This information is accompanied by vehicles sold in Turkey, the price of diesel fuel in vehicles as the average price per kilometer by that 0,975 Euro ((0,975 Euro x 6,4 liters) / 100 km=0,0624 Euro).

When comparing the amount of fuel consumed per kilometer of the vehicle carrying the test tubes with the A-brand drone, an expenditure of 0,0624 Euro is incurred against the 0,0041 Euro expenditure when the A-brand drone is used. As a result, a minimum of 0,0624-0,0041= 0,0583 Euro per kilometer is achieved in the transport of test tubes with the A-branded drone. It corresponds to 93% as a percentage.

CONCLUSION

TRIZ, education, transportation, communication, etc. today is a systematic problem-solving approach that is used and will be used in many areas. It is a creative thinking technique that does not propose a direct solution but directs the person to produce a correct and fast solution. In this study, the TRIZ method was proposed to solve a problem encountered in the health sector. The alternative method that can be used for the transfer of the samples from the FHC in the province of Amasya to the research laboratories was searched and our problem was transformed into a TRIZ problem. TRIZ's solution suggestions were evaluated and it was concluded that the transportation could be done with a drone. The drone to be used in the transportation process must have a special compartment that can carry at least 3kg load. It also appears that we need a drone with a lightweight, durable case and minimal energy consumption. When the transportation was carried out using an industrial drone which was available in the market and we carried out the same job using the carrier vehicle, the cost analysis was performed for the two different transportation operations that were performed and the situation was evaluated. When the drone is used to compare the amount of burner per kilometer of the vehicle carrying the test tubes, an expenditure of 0,0624 Euro is spent with the carrier vehicle against the expenditure of 0,0041 Euro. According to these data, it is concluded that a minimum 0,0624-0,0041 = 0,0583 Euro per kilometer gain is achieved in the transport of test tubes with a drone. This result corresponds to an average gain of 93 %.

This study using the drone can also be used to transport test kits to medical centers. Thus, person-to-person contact will be reduced, enabling faster and more testing during epidemic periods.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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