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Measurement of OSPF-MPLS-TE-FRR Line Transitions and Data Losses

M. Oğul, N. Akçam, N. Erkan

***Abstract*— In this paper, when using Open Shortest Path First (OSPF) and Multi Protocol Lable Switching-Traffic Engineering (MPLS-TE) in Internet Protocol (IP) packet switching networks recover time was tested and compared and during that time amount of data lost in case of the link overload and failure. For the accuracy of measurements, two different traffic generators were used and the differences were compared. One of them is Simena device and the other one is a Hping3 program working with Linux platforms. Line transitions and data losses were measured seperately with Simena and Hping3, calculations were performed and results were compared.**

Index Terms— **Multi Protocol Lable Switching (MPLS), Traffic Engineering (TE), Fast Reroute (FRR), Open Shortest Path First (OSPF)**

I. INTRODUCTION

NOWADAYS, continuity of IP (Internet Protocol) networks, used to transport a variety of data on the same physical environments, detection of alternative ways at the time of issue and minimizing data loss have become critical.

In traditional routing protocols, because of the long duration of making alternative solution at the time of issue, during this time, as a serious loss of data and also reputation has been experienced, this problem has been reduced significantly thanks to MPLS (Multi-Protocol Lable Switching) technology. In addition, the transmission of critical data without discarding in the line traffic resulting with different reasons at networks carrying critical data and normal data simultaneously, has gained importance.

Indispensability of TCP / IP results from its flexible configuration, based on packet switching technology[1-3]. As many applications only can run on circuit-switched systems in the past, today is run over IP. In contrast to the bus that packets will be sent in circuit switching, is determined in advance, there is no such a necessity in packet switching. Today, of course, there are circuit-switched configurations, however, packet-switched networks and the Internet, the largest of them are so developing that almost all types of communication take place via the Internet, a packet-switched configuration.

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II. PREVIOUS WORKS

OSPF routing protocol are the most important of the IGP (Interior Gateway Protocol) protocols [4]. Although it mostly compares with the RIP (Routing Information Protocol) protocol in terms of their technology used, that is far superior protocol than RIP protocol. As RIP determines routing tables with the logic of the distance vector, OSPF determines routing tables according to the link mode algorithm.

QoS (Quality of Services) on IP networks, simply, can be defined as sorting according to certain criteria of IP packets and discriminating to the parsed IP packets. On IP networks, there are two different QoS mechanisms as IntServ and DiffServ. In today's IP networks, in case of not being used any QoS mechanism, “best-effort” treated accordingly to the packages. All the received packages in 'Best-effort' are treated as a single cluster regardless of the traffic characteristics. Each received package is tried to be sent without decomposition of data type [5-6]. Each traffic type in IntServ is edited the necessary resource allocation from end to end along the bus until reaching the target before receiving to the IP network. In DiffServ, instead of the resource allocation from end to end for each traffic type, classification is made between types of traffic. These types of traffic are processed by providing the necessary resource in each node (hop / router).

MPLS is a quite new mechanism for package transmission than the IP that has the label switching. When the configuration of the OSI (Open System Interconnection) layer is considered, MPLS label is located between layer 2 and layer 3. Packages are transmitted by using the label information which is smaller than IP. Label information depending on the use, may also be appropriate for some criteria such as QoS and source IP as well as the target IP. MPLS is used for not only IP packets, but also transmission of the other protocol packets, running in layer 3 [7,8].

TE (Traffic Engineering) that comes with MPLS is probably one of reasons about the most used of MPLS. It can be said that TE is a transaction, controlling the effective use of resources and increasing of network performance when sending the data traffic across the network [9]. In environments that classic routing algorithms are used with TE, the observed two questions will be gotten over. One of them is the risk of using the buses, defined as the shortest bus, although they are not more available than the longest buses. The other one, as a result of the use of the shortest bus, is the

blockage of the buses and despite of continuing of the blockage, non-using of available alternative buses.

One of the key points is also using of RSVP (Resource Reservation Protocol) signaling [10] in the MPLS-TE. RSVP signaling is also used in this study.

In addition, when carrying the data from high-capacity lines, in the issues of link or node, in order to minimize the risk of cuts, either one-to-one link back-up must be kept or MPLS-TE stand-by tunnels must be formed. Keeping a backup of high-capacity circuits are highly cost solution. Instead, forming of MPLS-TE tunnel backups would be much cheaper and flexible solution. Link Protection with MPLS-TE is called as FRR [11]. There are two types as Link Protection (LP) and Node Protection (NP) of FRR.

III. The Test Network

The experiments presented in this article were conducted on a real-life research test network is shown in Fig.1. The network was built in laboratory and consisted of three Cisco 12000 Series director (GSR) [12], two Cisco 3560 Series Ethernet key, two traffic generator (Simena), two testPC. We used Hping3 utility program in testPC's. The routers are made with a variety of chassis sizes and types. Technical properties of GSR 12000 routers series is given in Table I.

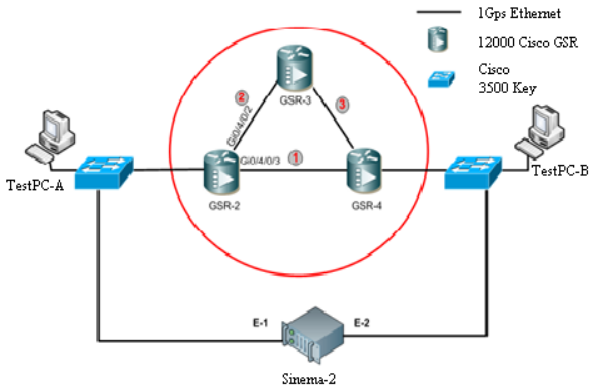

Fig.1. Experimental service setup (Network Topology)

TABLE I
TECHNICAL PROPERTIES OF GSR 12000 ROUTERS SERIES

CİSCO 1200 family	CİSCO 12004	CİSCO 12008	CİSCO 12012
Bandwidth	5 Gbps	10-40 Gbps	15 to 60 Gbps
Configurable Chassis Slots	4	8	12
Configurable Switch Fabric Slots	1	5	5
Maximum Line Card Support	3	7	11
OC-3/STM-1 Ports[1]	12	28	44
OC-12/STM-4 Ports[1]	3	7	11
Redundancy Options	GRP, Line Card, Power	GRP, Line Card, Power, Fans, Fabric	GRP, Line Card, Power, Fans, Fabric

For the accuracy of measurements, two different traffic generators were used and the differences were compared. One of them is Simena device and the other one is a Hping3 program working with Linux platforms.

IV. Measurement And Calculation

IV.1. Measurement of OSPF+MPLS-TE-FRR Line Transitions and Data Losses

In each of 3 router in Fig.1., OSPF is used as routing protocol. Besides, MPLS-TE and FRR spesifications of routers were activated in order to minimize the datalosses during interruption and quick package switching. Through MPLS-TE-FRR, alternative tunnel definition is performed for the (1) numbered way of the topology in Fig.1., and it traffic's routing directly to backup tunnel was provided in case of an intteruption in this way. In definitions of primary tunnel and backup tunnel, Label Switched Path **(**LSP) way was cleared by giving IP's of each of routers on LSP. During tests, because of the importance of configuration on GSR2, MPLS and OSPF configurations are given below. Line transitions and losses were measured seperately with Simena and Hping3, calculations were performed and results were compared.

→ explicit-path name explicit_tunnel-te24 → *Way definition for TE tunnel*
!Primary link
index 10 next-address strict ipv4 unicast 1.1.1.3
index 20 next-address strict ipv4 unicast 10.200.100.12
!
→ explicit-path name explicit_tunnel-te234 → *Way definition for backup TE Tunnel*
index 10 next-address strict ipv4 unicast 2.2.2.2
index 20 next-address strict ipv4 unicast 3.3.3.3
!
→ interface tunnel-te24 → *TE Tunnel from GSR2 to GSR4*
ipv4 unnumbered Loopback0
autoroute announce
→ destination 10.200.100.12 → *GSR4's loopback IP*
→ fast-reroute → *If TE24 is down, FRR will be active*
path-option 1 explicit name explicit_tunnel-te24
!
→ interface tunnel-te234 → *Backup TE Tunnel from XJSR2 to GSR4*
ipv4 unnumbered Loopback0
destination 10.200.100.12
path-option 1 explicit name explicit_tunnel-te234
!
router ospf 1
log adjacency changes
router-id 150.1.2.2
area 0
mpls traffic-eng → *MPLS TE tunnels will be used in OSPF*
interface Loopback0
!
interface GigabitEthernet0/4/0/0
passive enable
dead-interval 4
hello-interval 1
!
interface GigabitEthernet0/4/0/1
dead-interval 4
hello-interval 1
!
interface GigabitEthernet0/4/0/2
network point-to-point
passive disable
dead-interval 4
hello-interval 1
!

```
interface GigabitEthernet0/4/0/3
network broadcast
passive disable
dead-interval 4
hello-interval 1
!
mpls traffic-eng router-id Loopback0
mpls traffic-eng multicast-intact
!
   →   rsvp                          → It leads TE and FRR labels to
                                       be delivered.
 interface GigabitEthernet0/4/0/2
!
interface GigabitEthernet0/4/0/3
!
   →   mpls traffic-eng              → Interfaces which are MPLS
                                       TE will be active
interface GigabitEthernet0/4/0/2
!
interface GigabitEthernet0/4/0/3
   →   backup-path tunnel-te 234     → If Gİ0/4/0/3 interface is
                                       interrupted, the traffic will be routed to TE234 tunnel
```

In configuration of GSR2 Router, two TE tunnels, named "tunnel-te 24" and "tunnel-te 234", were created, because there were two alternative ways from GSR2 to GSR4. The start point of both of two tunnels was determinated as GSR2 and endpoint was determinated as GSR4. The interfaces of these additional new tunnels must be inside of OSPF, because tunnels were added as new interfaces. In MPLS configuration; the interfaces, which will be made TE, was detected and transition tunnel information (backup-patlı tunnel-te 234) was entered, in case of an interruption in primary used one of these interfaces. According to this; GSR2 router will use GiO/4/0/3 interface and naturally "tunnel-te24" tunnel, already related with this interface, for packages to TestPC-B. When any information of interruption on this interface is delivered to the router, router will use the tunnel-te234 because router sees interface an tunnelinterface as "down". It will do it by using FRR method. So, quickly routing can be performed in miliseconds, in case of any interruption. Line transition time is guarantied as under 50 ms on MPLS-TE-FRR used area [10-11].

A. *QSPF+MPLS-TE-FRR Transition Time Measurements and Calculations with Hping3 Program.*

In Fig.1. topology, while using of OSPF+MPLS+TE+FRR between routers; whereas 1Gbps speeded ① numbered way was primary way of the traffic from TestPC-A to TestPC-B, traffic's transition time to alternative ways ② and ③ were calculated with Hping3 program by interrupting ① numbered way. In Fig.2., two results of OSPF+MPLS+TE+FRR measurements is shown and calculations with results in Table II.

The second measurement in Fig.2. was completed in 9,061 second. According to this; 2000/9,06sn=~247 packages was sent per second and 1 of them was lost. According to 247 packages is sent per second, 1 package is sent in l/247=~0,00404 sn=4,04ms. All of the test results and calculated transition times are shown in Table II. According to these results, MPLS-TE-FRR's average transition time was calculated as 4,5ms. Besides, all of the calculated transition times are shown in Figure 3.

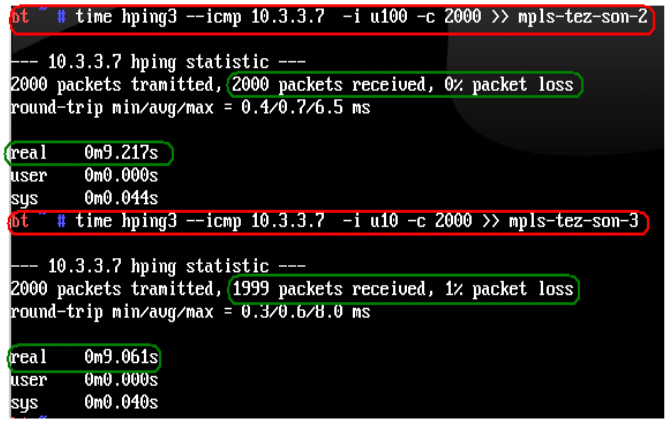

Fig.2. Hping3 OSPF +MPLS +TE+FRR transition test results screen

As seen in Table II; because of package sending rareness of measurements with Hping3, sampling interval is wide. Naturally, package loss cannot be detected and transition time is calculated as 0 in some tests, because of sensitive tests performing.

TABLE II
OSPF-MPLS-TE-FRR MEASUREMENT AND CALCULATING RESULTS WITH HPING3

Hping3 OSPF-MPLS-TE-FRR	Test1	Test2	Test3	Test4	Test5	Test6	Test7	Test8	Test9	Test10
Transmitted Packet Number	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Received Packet Number	1999	2000	1999	1999	1999	1999	1999	1999	2000	1999
Loss Packet	1	0	1	1	1	1	1	1	0	1
Transmit Time (sn)	8,091	9,217	9,061	9,82	9,08	9,127	9,076	9,147	9,362	9,582
Transmitted Packet / 1 sn	247,1	216,9	220,7	203,6	220,2	219,1	220,3	218,6	213,6	208,7
Transit Time ~ (ms)	4,04	0	4,53	4,91	4,54	4,56	4,53	4,57	0	4,79

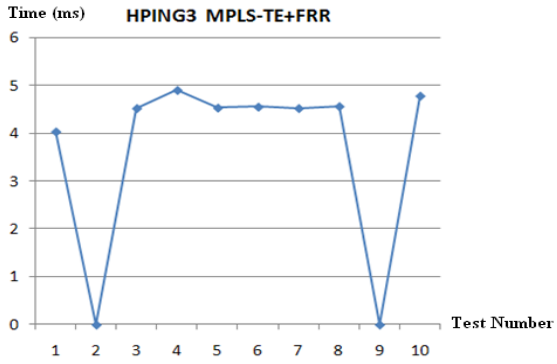

Fig.3. Hping3 OSPF +MPLS +TE+FRR calculated transit time

B. OSPF+MPLS-TE-FRR Transition Time Measurements and Calculations with Simena.

By using hand interface of Simena-2 machine which seems in Fig.1., TCP packages were sent to Simena's E2 interface through GSR2 and after the start of sending, packages losses were measured with Simena by interrupting of 1 numbered line. Transition times were calculated by using these results;

In Test-1, 2.000.000 TCP packages were sent by hand interface with l00.000 pps speed and 1.977.799 packages were received from E2 interface. During transition, 201 packages were lost. According to 100.000 packages sending per second, sending time for 201 packages is 201/100.000=0,00201s=2,01ms. In Table III, measurement

TABLE III
OSPF-MPLS-TE-FRR MEASUREMENT AND CALCULATING RESULTS WITH SIMENA

Simena OSPF-MPLS-TE-FRR	Test-1	Test-2	Test-3	Test-4	Test-5	Test-6	Test-7	Test-8	Test-9	Test-10
Transmitted Packet(x1000)	2.000	2.000	6.000	6.000	10.000	10.000	1.000	1.000	100	100
Received Packet	1.999.799	1.999.800	5.999.400	5.999.425	9.999.040	9.998.546	999.899	999.920	99.985	99.990
Loss Packet	201	200	600	575	960	1.454	101	80	15	10
Packet Transmit Velocity (pps)	100.000	100.000	300.000	300.000	500.000	500.000	50.000	50.000	5.000	5.000
%Packet Loss	0,01	0,01	0.01	0.009	0.0090	0.014	0.01	0.0080	0.015	0.01
Transit Time (ms)	2,01	2	2	1,916	1,92	2,908	2,02	1,6	3	2
Packet Size (byte) (TCP)	120	120	120	120	120	120	120	120	120	120

results for different packages numbers and speeds and transition times calculated from these results, are shown. Besides, all of the calculated transition times are shown in Fig. 4. sampling interval is closer than done with Hping3, because packages can be sent by Simena with different speeds and between 100.000 and 10.000.000 per second. So, the measurements and calculations are more sensitive.

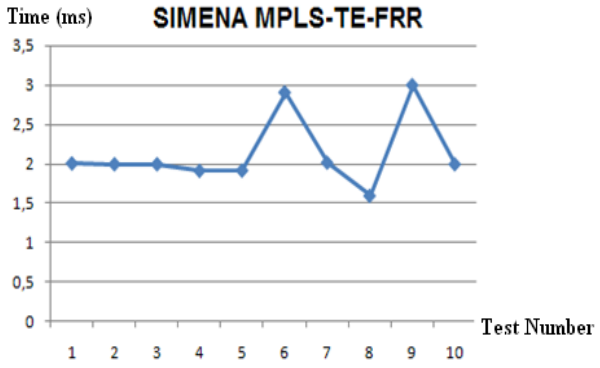

Fig.4. Simena OSPF-MPLS-TE-FRR calculated transit time

Package losses are not so much, because MPLS-TE-FRR transitions take very little time. So difference between Simena transmission and receiving interfaces, which is shown in Fig.5., are little as indistinguishable.

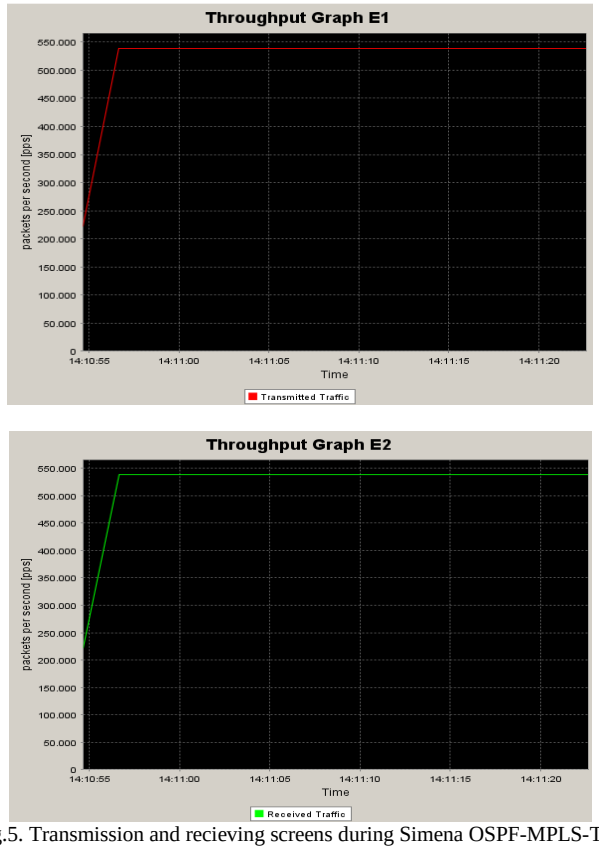

Fig.5. Transmission and recieving screens during Simena OSPF-MPLS-TE-FRR transition

IV.2. Comparing Transition Times of OSPF and OSPF+MPLS-TE-FRR

In measurements and calculations with Hping3 and Simena, both of two results are seen as close to each other. But measurement results of Simena are thought as more sensitive, because more packages can be sent in less time with Simena. In Fig.6., OSPF [13] and OSPF-MPLS-TE-FRR's calculated transition times were compared.

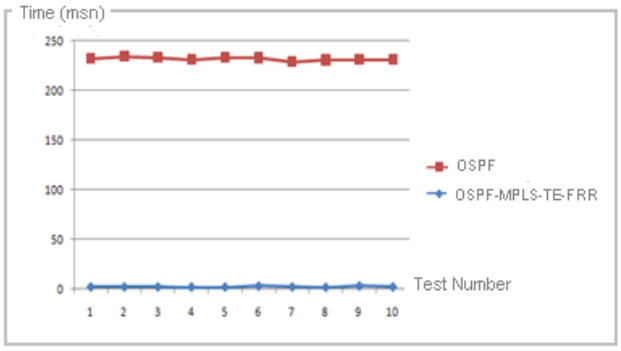

Fig.6. Comparative results of OSPF and OSPF-MPLS-TE-FRR's transition time

V. CONCLUSION

In this study, "data losses and transition time to backup line in line interruptions of OSPF, which is the most common used routing protocol," and "data losses and transition time to backup line when MPLS-TE-FRR technology is used" were compared. Also, protections of critical data were evaluated, in case of a capacity overflow in line without any interruption.

Protection of critical data was transition time to backup line is circa 220msn, when just OSPF protocol was used and there was an interruption in line. But it is 2ms in MPLS-TE-FRR and this is interesting. MPLS-TE-FRR technology guaranties the transition time under 50ms [14]. The reason of longer time in OSPF is the rerunning of Dijkstra algorithm and finding the alternative ways. Extending of line transmission time leads data losses, and naturally costumers' dissatisfaction and low quality service. Besides, one of the most common problems in shared areas is the line forcement to carry over its capacity. In this case, manufacturers generally junk the last coming packages as default evaluated, in case of a capacity overflow in line without any interruption.

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REFERENCES

[1] L. Parziale, D.T. Brit, C. Davis, J. Forrester, W. Liu, C. Matthews, N. Rosselot, TCP/IP Tutorial and Technical Overview Eight Edition // IBM**,** USA, 2006.

[2] J. Doyle, "Routing TCP/IP Volume I", Cisco Press, USA, 1998, pp.9-357.

[3] M. G. Naugle, Illustrated TCP/IP, John Wiley & Sons**,** USA, 1998, pp.62-64.

[4] K. Mishra and A. Sahoo, S-OSPF: A Traffic Engineering Solution for OSPF based Best Effort Networks, IEEE GLOBECOM 2007 proceedings, 2007, pp.1845–1849.

[5] C. Hattingh and T. Szigeti, End-to-End QoS Network Design: Quality of Service in LANs, WANs, and VPNs, CiscoPress, USA, 2004, pp.44.

[6] M. Tanvir, A. M. Said, Decreasing packet loss for QoS sensitive IP traffic in DiffServ enabled network using MPLS-TE, Information Technology (ITSim), 2010 International Symposium 15-17 June 2010, Vol.2, pp.789-793.

[7] T. Barabas, D. Ionescu, S. Veres, PIM-SSM within DiffServ-aware MPLS traffic engineering, 6th IEEE International Symposium on Applied Computational Intelligence and Informatics, Timişoara, Romania, May 19–21, 2011, pp.263–268.

[8] D. Awduche, MPLS and traffic engineering in IP networks, IEEE Communications Magazine, No.12 (37). 1999, pp.42–47.

[9] D. Awduche, J. Malcolm, J. Agogbua, M. O'Dell, J. McManus, Requirements for Traffic Engineering Over MPLS, RFC 2702, 1999.

[10] R. Braden, Ed., L. Zhang, S. Berson, et al., Resource ReSerVation Protocol (RSVP), RFC 2205 ,Version 1, 1997.

[11] L.D. Ghein, MPLS fundamentals: forwarding labeled packets, Cisco Press, USA, 2007.

[12] N. Akçam, M. Ogul, Optimizing Data Transport by Using MPLS-TE-FRR and QoS., International Journal on Communications Antenna and Propagation ,Vol. 2, N. 5, October 2012, pp.283-289.

[13] N. Akçam, M. Ogul, "Measurement of OSPF line transitions and data losses", Energy Education Science and Technology Part A: Energy Science and Research 2012 Volume (issues) 29(2), pp.979-988

[14] Liotine, M., "Mission-critical network planning", Artech House Inc., USA, 100, 2003.

BIOGRAPHIES

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Developing a virtual driving simulator for educational purposes

İ. Öztel and C. Öz

***Abstract*—Analyzing traffic accidents, human behavior represents the most relevant problem; especially drivers' behavior. In this regard, driver education becomes essential. In our project, we present a simulator consisting of both software and hardware including, a steering wheel, a pedal system, a shift knob, a seat and a visual display. This system needs a virtual platform modeled using Google Sketchup-3D Modeling Program. We used a Unity Game Engine in order to enable the platform. Owing to this simulator, prospective drivers will be able to acquire experience in a virtual environment without the risks of the real world.**

In the simulator, the driver is penalized for every infraction according to the Turkish traffic rules. For instance, if the driver runs a red light, then penalty points are given. If the driver does not follow traffic signalization, again the simulator penalizes the driver with penalty points.

Index Terms— **Driving simulator, driver education, game programming, virtual reality, traffic accident prevention**

I. Introduction

MANY of the accidents that happen in traffic are due to human failure, vehicles, state of roads and signposts whose positions are inadequate. According to an analysis made by the "Republic of Turkey General Directorate of Highways", the most relevant factor is the human factor, especially drivers. The rate of accidents that occur because of drivers is approximately 90 percent (Table I) [1] and 1.24 million people die each year on the world's roads, according to the World Health Organization [2]. Moreover, according to OECD, the reported rate of accidents caused by young drivers in between the ages of 15 to 24 is 70 percent [3]. In this case, driver education becomes important, particularly for novice drivers. Traditionally, the novice driver education procedure is to have him/her drive in real traffic conditions. Of course, there are several risks every time the inexperienced driver is in this situation. In order to avoid those risks, driving simulators can be used effectively.

Simulators have been used for 50 years [4] for a wide range of purposes. One of which is driving. In vehicle simulators, not only the operation of cars can be simulated, but also of trucks, tanks, trains, planes, etc… In the 1970s, the first step was taken towards creating driving simulators [5] and they have developed rapidly in recent years [6]. Driving simulators may consist of various pieces of equipment differing from each other. For example, some simulators are controlled with a keyboard while others, with a steering wheel. Furthermore, a real car can be used as a simulator. A virtual display can sometimes be a monitor, sometimes a projector screen and sometimes a head mounted display. Driving simulators are categorized into three groups [7, 8]: low-level, mid-level, high-level. Generally, low-level simulators include a steering wheel, pedals and a computer, mid-level simulators have also a motion platform, a visual display and a computer or computers, high-level simulators use Stewart platform or a hexapod for sense of motion [9].

TABLE I
DEFECT RATES IN TRAFFIC ACCIDENTS BETWEEN 2007 AND 2011, IN TURKEY [1]

Year	Driver	Pedestrian	Passenger	Total Human Factor	Vehicle	Road
2007	98.03	1.64	0.09	99.76	0.14	0.11
2008	90.53	8.37	0.43	99.33	0.26	0.42
2009	89.60	9.09	0.41	99.10	0.29	0.61
2010	89.72	8.97	0.36	99.05	0.33	0.63
2011	90.20	8.51	0.39	99.10	0.30	0.60

When we look at low-level simulators, the following studies appear; of course, these are some examples, not all of them. Hoe C. Lee et al. presented a study in which there was a low-mid driving simulator used to access older drivers' driving skills. Driver data were collected and analyzed. The conclusion of the study, as expected, was that older drivers' driving skills decrease with age [10]. David B. Kaber, et al. presented another study. The aim of the study was to determine the effects of cognitive, visual and simultaneous distractions on vehicle operational controls, such as breaking, and tactical, such as maneuvering. Tactical control needs more attention than operational control and visual and cognitive distractions increase driver workload were observed [11].

This section covers some examples of mid-level driving simulators. Jean-Michel Auberlet and his team conducted a study on the impact of perceptual treatments on drivers' behavior. The study included three sections. In the first section, simulators were used and two perceptual treatments were selected, i.e. rumble strips on both sides of the centerline and sealed shoulders, from the five tested to help drivers maintain lateral control when driving on rural crest vertical

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curves. Secondly, a diagnostic device was developed in order to evaluate the impact of perceptual treatments on the driver's performance, and installed upstream and downstream the field site. In the last step, data were collected from the simulator in two different circumstances, before and after the centerline rumble strips were installed. Finally, the comparison of the results showed that the rumble strips on both sides of the centerline and sealed shoulders were the most effective treatments. It was observed that using simulators is helpful in the road design process [12]. "A Driving Simulator Based on Video Game Technology" is another presented study in the group of mid-level simulators. The study aimed to use the simulator as a platform for studies of serious games and to use for traffic education such as ours [13]. Moohyun Cha, et al. presented another study at this level. In the study, motion data samples were collected from a real vehicle and transformed into data structures. The data were used in the virtual driving simulator for motion effects [14].

There also are many studies on high-level simulators. For example, Min Kyu Park, et al. performed a four sections study. First, they developed a motion platform and motion controller, then a new washout algorithm was developed to actualize the real motion of a vehicle to the workspace of the simulator. The next step was to develop a visual and audio system for a more realistic feeling [6]. Finally, for the communication and monitoring among the subsystems, an integration system was developed. Yi Tang at al. presented a simulation study that utilized a 6-DOF Stewart mechanism. The simulator was developed for heavy vehicles. The simulator's software collects data as signals from the interaction of the driver with the accelerator, the brake, etc... The data are identified by the software, and then outputted to the simulator's components. Owing to that, a system that ensures a real-time interaction closely similar to that of a real vehicle [15].

II. THE DRIVING SIMULATOR

Our developed virtual driving simulator includes software and hardware. The system is comprised of software installed onto a computer where the simulation program runs, and to a steering wheel with a driver's seat, a projector, and a projection screen.

The steering wheel is a Logitech G25 Racing Wheel, which contains a force feedback racing-wheel, a shifter module; gas, brake and clutch pedals. The steering wheel provides an authentic feel. The speed can be changed with the six-speed shifter and it has a push down reverse gear.

We used the Google Sketchup 3D Modeling Program to create the virtual environment, which is not imaginary. We used the central campus of Sakarya University for the modeling (for example Fig. 1 and Fig. 2). The campus was investigated on Google Earth. The buildings on campus were visited individually and photos were taken. In the next step, the buildings were created with the modeling program and suitable textures were added. Sketchup uses ".skp" file extensions, which are useless for the Unity. We needed ".fbx" file extensions for the buildings in the Unity Game Engine, so the 3D models (road, building, etc.) were exported with ".fbx" file extensions. The buildings were later combined with the game engine.

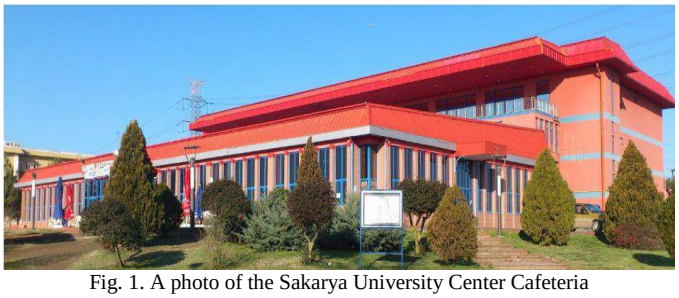

Fig. 1. A photo of the Sakarya University Center Cafeteria

Fig. 2. A 3D model of the Sakarya University Center Cafeteria

The virtual original campus does not possess enough elements; therefore, a more complex scenario was required for driving education. For instance, signaling systems were installed at the junctions; new signs were added in the virtual campus according to the scenario. In addition, the simulator needed a car after the creation of the virtual environment. We used one of the ready to use cars from the Unity Asset Store car tutorial. The car was then, combined with virtual environment.

Fig. 3. The virtual driving simulator

Fig. 4. The virtual driving simulator

There are penalty points for traffic violations in our scenario. The penalty points were determined by examining the guide, which is available on the website of Turkish National Police Traffic Services Department [16]. An example of such possible violations is "failure to comply with the rules of the red light", a twenty penalty points violation according to the penalties guide. Another example of a twenty penalty points is "failure to comply with traffic signs". Using those criteria, we determined all penalty points for each violation in the simulator.

Fig. 5. An example view of the stage of the simulator

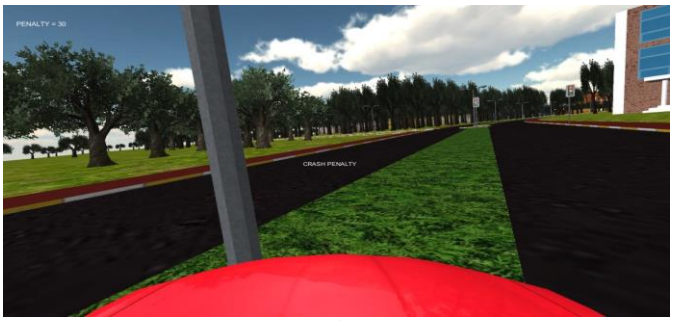

Fig. 6. Picture of a crash penalty

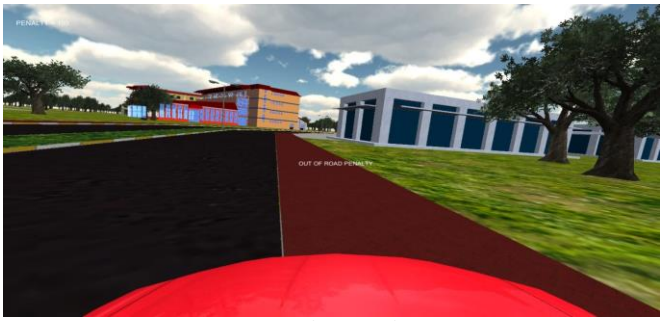

Fig. 7. Picture of an out of road penalty

Afterward, Java script was used to develop the penalization system. For example, if a driver runs a red light, the driver receives 20 penalty points. The penalties for the violation of the rules are given according to the Traffic Services Department penalty guide.

TABLE II
SOME OF PENALTY RULES VIOLATIONS AND THEIR PENALTY POINTS

Rules	Penalty Points
Failure to comply with the rules of the red light	20
Exceeding the speed limit from %10 to 30%	10
Driving detrimentally (go out of the way in the simulator)	10
Failure to comply with traffic signs	20
Parking where parking is prohibited	10
Exceeding the speed limit by more than 30%	15
Failure to comply with the rules of right and left turn	20

III. CONCLUSION AND FUTURE WORKS

In this study, a low cost virtual driving simulator was developed and established for the novice drivers' education. It uses a driver seat, a steering wheel, and a dashboard to provide a feeling similar to that of a real car. A projector is used to display the virtual driving environment on a screen positioned in front of the system. The software consists of a simulation program developed at the Unity, and 3D models created on Sketchup. We generated virtual scenarios intended as a driving education tool. Some scenarios are designed to teach and test the driver in "real" traffic conditions' simulations. The driving skills of the users, such as behavior at traffic light, speeding, and obedience to traffic signs, are improved and tested with the system. We determined penalty points for violations observing the Turkish traffic rules. Each user's error is penalized by the simulator's program according to the specified points and rules. Our simulator can be used to educate, improve driving skills, and teach traffic rules to novice drivers, using entertainment. The next goal is to add a few virtual cars and human beings with artificial intelligence, and engage participants in utilizing the system to determine its success.

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REFERENCES

[1] Republic of Turkey General Directorate of Highways. (2011, August). Trafik kazaları özeti 2011 [Online]. Available: http://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Trafik/TrafikKazaOzet.pdf.

[2] World Health Organization. (2013, March). 10 facts on global road safety [Online]. Available: http://www.who.int/features/factfiles/roadsafety/en/.

[3] Organisation For Economic Co-Operation And Development. (2006, October). Young Drivers: The Road to Safety [Online]. Available: http://www.internationaltransportforum.org/jtrc/safety/YDpolicyBrief.pdf.

[4] N. Goode, P.M. Salmon, M.G. Lenne, "Simulation-based Driver and Vehicle Crew Training: Applications, Efficacy and Future Directions," in Applied Ergonomics, vol. 44, 2013, pp. 435-444.

[5] B. Richter, "Driving Simulator Studies: The Influence of Vehicle Parameters on Safety in Critical Situations," in Society of Automotive Engineers, Warrendale, PA, 1975, pp. 91-99.

[6] M. K. Park, M. C. Lee, K. S. Yoo, K. Son, W. S. Yoo, M.C. Han, "Development of the PNU Vehicle Driving Simulator and Its Performance Evaluation," in International Conference on Robotics & Automation, vol. 3, 2001, pp. 2325-2330.

[7] K. H. Siang, "Design and development of a virtual reality fixed base driving simulator," M.S. thesis, Dept. Mechanical Eng., Universiti Teknologi Malaysia; johor, Malaysia, 2008.

[8] J. Justice et al., "Interactive 3D application development using EON professional for creating 3D visualization," Irvine, CA, United States, 2010.

[9] N. Fouladinejad, N. Fouladinejad, M. K. Abd Jalil, J. M. Taib, "Modeling Virtual Driving Environment for a Driving Simulator," in IEEE International Conference on Control System, Computing and Engineering, pp. 27-32, doi: 10.1109/ICCSCE.2011.6190490.

[10] H. C. Lee, A. H. Lee, D. Cameron, C. Li-Tsang, "Using A Driving Simulator To Identify Older Drivers At Inflated Risk Of Motor Vehicle Crashes," in Journal of Safety Research, vol. 34, 2003, pp. 453-459.

[11] D. B. Kaber, Y. Liang, Y. Zhang, M. L. Rogers, S. Gangakhedkar, "Driver Performance Effects of Simultaneous Visual and Cognitive Distraction and Adaptation Behavior," in Transportation Research, vol. 15, 2012, pp. 491-501.

[12] J. Auberlet, M. Auberlet, F. Rosey, F. Anceaux, S. Aubin, P. Briand, M. Pacaux, P. Pacaux, P. Plainchault, "The Impact Of Perceptual Treatments On Driver's Behavior: From Driving Simulator Studies To Field Tests—First Results," in Accident Analysis & Prevention, vol. 45, 2012, pp. 91-98.

[13] M. Lebram, H. Engström, H. Gustavsson, "A Driving Simulator Based on Video Game Technology," in Linköping Electronic Conference Proceedings, 2006, pp. 39-43.

[14] M. Cha, J. Yang, S. Han, "An Interactive Data-Driven Driving Simulator Using Motion Blending," in Computers in Industry, vol. 59, 2008, pp. 520-531.

[15] Y. Tang, X. Zhang, L. Li-hua, "Research on Driving Simulation System for Special Heavy Vehicle," in Audio Language and Image Processing (ICALIP), 2010, pp. 208-213.

[16] Turkish National Polis Traffic Services Department. (2013). 2013 Yılı Trafik İdari Para Ceza Rehberi [Online]. Available: http://www.trafik.gov.tr/Haberler/Sayfalar/2013_ceza.aspx.

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Advantages of the Walsh Functions in the Measurement of Reactive Power in the Electric Power Systems

A. N. Abiyev

***Abstract*—In this paper a reactive power (RP) measurement method is proposed. Application of Walsh function (WF) based algorithms allowed to simplify the multiplication operations required for the evaluation the RP in the single-phase and three-phase power systems. One of the unique advantage of the used method is toe eliminate the phase shift operation between the voltage and current signals that is required foe measurement of RP. Limitations and proposals for future performance enhancements of the analyzed algorithms are also discussed. The simulations performed by use of Matlab 6.5 environment have confirmed the validity of the algorithms for measuring of RP in power systems. The simulation results have demonstrated the advantages of Walsh functions in that the computational demands is substantially reduced.**

Index Terms— **measurement, reactive power, unbalanced three-phase systems, instantaneous power signal, Walsh function.**

I. Introduction

THE reactive power (RP) is an integral part of the total electric power in power systems. In spite of the negative effect of the reactive power on the normal operating of the power systems, reactive power is the inherent phenomena of the most of power system components, such as electric machinery, energy transmission and distribution systems, power transformers, etc. All these power systems components have the behavior to store an electromagnetic energy, because they include the reactive components, mainly, inductance in the wide range power systems applications. That's just the main cause for the existence of the reactive power in power systems.

The higher the reactive power the larger the current required for transmission the same amount of energy from source to the user. This problem significantly reduces efficiency of the energy transmission in transmission and distribution lines. Different type of compensation circuits have been developed and applied for the increasing an efficiency of the energy transmission process through compensation of reactive power. The level of reactance to be imposed by the compensation system depends on the value of the reactive power in existing power system, that is why, proper measurement of reactive power in power systems is the one of the extremely important scientific research problems.

In the field of measurement of reactive power the various methods and the algorithms have been developed and published in the scientific journals and international conference proceedings during last decade. The most of the known methods for measuring reactive power are based on the digital measuring approaches, although analog measurement methods are the most suitable for the application where the low-cost and simplicity are of the prime importance. Among the existing methods the reactive power measurement methods using different type of transforms such as Fourier, FFT, DFT, Wavelet, Walsh, etc form class of measurement methods designed for application as the imbedded part of complex power measurement and analysis systems.

Fourier and Wavelet transforms based measurement methods require generation set of orthogonal waveforms (discrete or analog). Since these transforms require multiplication and summation of the signals in the complex domain, the applications of Fourier as well as the Wavelet transform approaches are accompanied with the increase of the volume of required operations resulting to the high cost and less speed.

In this aspect use of Walsh functions for reactive power measurement reduces the volume of operations required for multiplication of the input signal by the Walsh function. Since Walsh functions have only two values, +1 and -1 over the normalized period, it becomes significantly simple to perform multiplication operation. Really, the multiplication of the signal by +1 is equivalent to the original signal. In other words, signal remains unchanged.

Multiplication of the given signal by -1, actually, is the same operation as the inverting of the original signal. This is main advantage of the Walsh transform based method of reactive power measurement. By use of this approach the series of instruments have been developed, investigated, and simulated for single- as well as the three-phase power system networks.

Among the existing RP measurement methods the methods using the shifting of the one of the power components, voltage or current, by the $\pi/4$, and then multiplication these components, are widely used in applications where the requirements to the power network harmonic distortions are not critical. One way to eliminate an effect of input frequency

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change on the output result is the use of frequency insensitive digital sampler for shifting the input voltage signal by $\pi/4$.

The design and implementation of RP sensors and measurement instruments is currently dictated by the strong demands to the electrical energy savings during transmission and distributions. The evaluation of the RP is also one of the important tasks in electric power industry, especially in the electrical energy quality estimation and control. The RP influences directly to the power factor and as a result overloads the connecting cables between the electrical energy sources and energy user and plays a vital role in the stable operation of power systems. Moreover control of RP and proper selection of the compensating method and corresponding devices mostly depend on the knowledge about the portion of reactive component in the total power.

The classic way to determine the reactive power includes evaluation of the reactive power by using the measured values of the apparent power *S*, and the active power *P*.

This way of RP evaluation requires the measurement of the root mean square (RMS) values of voltage U and current I, and then performing the multiplication operation in order to obtain apparent power S. But this operation is complicated due to the measuring of the RMS values of U and I, which are difficult to measure.

The extension of the wavelet transform to the measurement of RP component through the use of a broad-band quadrature phase-shift networks is demonstrated in [1]. This wavelet-based power metering system requires the phase shift of the input voltage signal. In [2] the application of new frequency insensitive quadrature phase shifting method for reactive power measurements has been verified by using a time-division multiplier type wattmeter. An electronic shifter based on stochastic signal processing for simple and cost-effective digital implementation of a reactive power and energy meter was developed in [3]. The development of a method using artificial neural networks to evaluate the instantaneous reactive power is described in [4]. In this method the back-propagation neural network is used to approximate the reactive power evaluation function. In [5] the digital infinite impulse response filters are used to measure the reactive power.

Although proposed algorithm allows to evaluate the harmonic components of the RP, the suggested method is still complex because the performing of the filtering procedures.

Most of known research works are based on using the method of averaging the value of the product of the current samples and the voltage samples with shifting to the quarter one of the samples (current or voltage) relatively to another.

Although the Fourier transform (FT) based digital or analogue filtering algorithms allow the evaluation of RP without shifting operation but a large number of multiplication and addition operations are required when applying FT algorithms for RP evaluation. For example for a 16 point DFT $16^2 = 256$ complex multiplications and $16 \times 15 = 240$ complex addition operations are required. The various algorithms (for example FFT known as the Cooley Tukay algorithm) have been developed to reduce the number of multiplication and addition operations by use of the computational redundancy inherent in the DFT. Unfortunately, FT based algorithms are still computationally complex.

The attraction of WF based approach to RP evaluation comes from the key advantages such as following:

(a) a requirement of IEEE/IEC definition of a phase shift of $\pi/2$ between the voltage and the current signals, typical for reactive power evaluation is eliminated from signal processing operation;

(b) the multiplication operation between tow digital data is replaced with the multiplication operation between digital data and positive or negative unit(+1 or -1). In other words, the multiplication operation is performed by simple altering the sign of the given digital data from positive to the negative sign so that to be multiplied by -1. Thus the WT analyzes signals into rectangular waveforms rather than sinusoidal ones and is computed more rapidly than, for example FFT. WT based algorithm contains additions and subtractions only and as a result considerably simplifies the hardware implementation of RP evaluation.

The authors in [6] have analyzed WT algorithms employed to energy measurement process and they have shown that the Walsh method represents its intrinsic high-level accuracy due to coefficient characteristics in energy staircase representation. Authors in [7] states that decimation algorithm based on fast WT(FWT) has better performance due to the elimination of multiplication operation and low or comparable hardware complexity because of the FWT transform kernel.

The basic idea of this WF based algorithm consists in the resolving of the voltage and current signals separately along the WFs, at first, and then obtaining the RP as the difference of the products of the quadrature components. At least four multiplication-integration, two multiplication, and one summation operations required for RP evaluation makes this algorithm comparatively complex and less convenient for implementation. It was the aim of this paper to evaluate RP component from instantaneous power signal without phase shift of $\pi/2$ between the voltage and the current waveforms with relatively less computational demands. This objective was achieved by using the WF.

The paper is organized as follows. In section two the WF based analogue and digital signal processing approaches for RP evaluation are described. The DSP based evaluation approach by using discrete is proposed in section three. In section four the simulation results of WF based RP evaluation system are given. Section five includes the conclusion of the paper.

II. A CONTINUES TIME AND DESCRETE TIME RP EVALUATION ALGORITHMS

A. Continues Time Measurement Algorithm

When in single-phase circuit a source voltage *u(t)* and a current flowing through load *i(t)* are the pure sinusoidal signals, the instant power $p(t)$ is given by [8]

$$p(t) = P - [P\cos 2\omega t + Q\sin 2\omega t], \quad (1)$$

where P is the average or active power in Watts, Q the reactive power in VARs, $\omega = 2\pi/T$ the power system

frequency in $rad/\sec$, $T=1/f$ the period in $\sec$, and $f=50Hz$ is liner frequency in Hz.

Time diagram representation of the right-hand side terms of (1) is shown in the Fig.1. Fig.2 represents the third order WF, $Wal(3,t)$ with the normalized period of $T/2$ [9].

Multiplication of both sides of (1) by the third order WF, $Wal(3,t)$ is given by

$$p(t)Wal(3,t)=PWal(3,t)-P\cos 2\omega t Wal(3,t)-Q\sin 2\omega t Wal(3,t) \quad (2)$$

Time diagram representation of the right-hand side terms of (2) is shown in the Fig.3. Note that multiplication of (1) by the $Wal(3,t)$ results in rectification of reactive component of the power, $p(t)$ (Fig.3, curve 1).

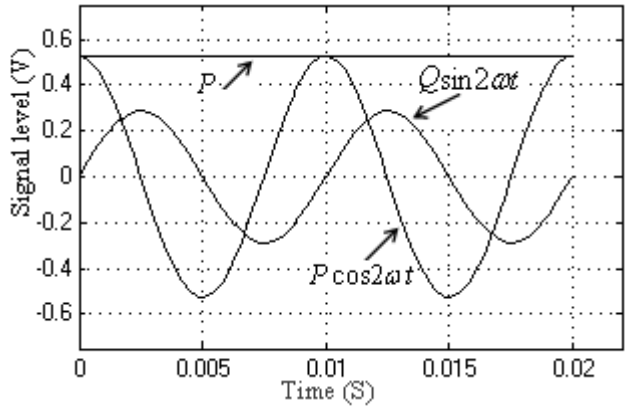

Fig. 1. Graphical interpretation of the power components defined by (1): $u(t)=2.4\sin\omega t$ $i(t)=0.5\sin(\omega t-0.5)$, $f=50Hz$

As the next step we take integral from both sides of (2) during time period of T:

$$\frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt=\frac{1}{T}\int_0^T PWal(3,t)dt-\frac{1}{T}\int_0^T P\cos 2\omega t\cdot Wal(3,t)dt$$
$$-\frac{1}{T}\int_0^T Q\sin 2\omega t\cdot Wal(3,t)dt \quad (3)$$

As can be seen from Fig.3 the average value of both product functions of $PWal(3,t)$ and of $PCos2\omega t\cdot Wal(3,t)$ during the time period T equal to zero. Thus, the first and second integrals in the right-hand side of (3) become zero. Thereby (3) is rewritten as follows

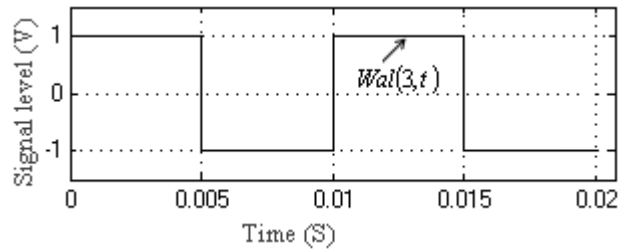

Fig.2. Graphical interpretation of third order Walsh function.

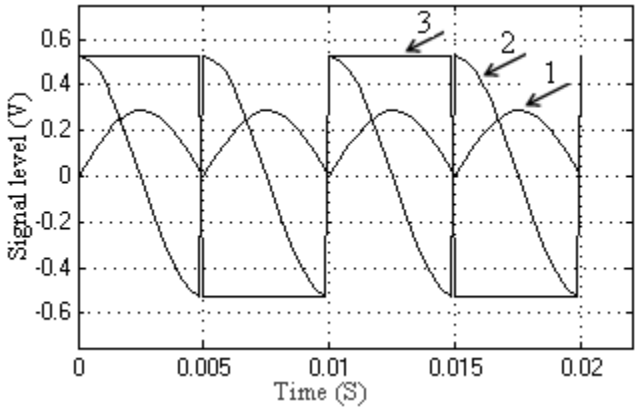

Fig.3. Graphical interpretation of third order Walsh function
1- $Q\sin 2\omega t\cdot Wal(3,t)$; 2- $P\cos 2\omega t\cdot Wal(3,t)$; 3- $PWal(3,t)$

$$\frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt=\frac{1}{T}\int_0^T Q\sin 2\omega t\cdot Wal(3,t)dt \quad (4)$$

Carefully look at the curve 1(Fig.3) and the integral given by (4) allow us to summarize that the average value of the oscillating reactive power can be measured by use of the derived algorithm without the phase-shift operation of the voltage(or current) signal to the $\pi/2$ with respect to the current(or voltage)signal.

Mathematical expression for RP evaluation is obtained from (4) considering Fig.3 (curve 1), as follows

$$Q=\frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt=\frac{1}{T}\int_0^T\left|Q\sin(2\omega t)\right|dt \quad (5)$$

Thus we obtained an equation (5) that allows measuring of the average value of the reactive power.

B. Discrete time Measurement Algorithm

To derive the digital measurement algorithm for RP an expression for instantaneous power given by (1) can be rewritten in discrete form as follows

$$p(n)=P-\left[P\cos\left(\frac{4\pi}{N}\cdot n\right)+Q\sin\left(\frac{4\pi}{N}\cdot n\right)\right] \quad (6)$$

Where $n=0,1,2,...,N-1$. N is the number of samples in power of 2. N is determined in accordance with Nyquist criterion, $N=T/T_s$, T_s is the sampling period.

For derivation of the digital algorithm for the RP evaluation we use the discrete expression of the WF [10]-[13]:

$$Wal(i,\beta_k)=(-1)^{\sum_{k=1}^{m}\left(\omega_{m-k+1}\oplus\omega_{m-k}\right)\beta_k} \quad (7)$$

where i is order of WF in the WF system, i=0,1,2,…,N-1, β_k is argument of WF and defines the bit(digit) coefficients of β_k represented in binary code, $\beta=(\beta_1,\beta_2...\beta_k)_2$, $\beta_k=0,1$, ω_m is the bit(digit) coefficients of ω_m represented in binary code, $\omega=(\omega_0,\omega_1,\omega_2...\omega_m)_2$, $\omega_m=0,1$, m is a binary representation of highest-order WF serial number in the WF

system. For evaluation of the reactive component of EP we use the third-order WF, $Wal(3,\beta_k)$. For the third-order Walsh function $\omega = 3$ therefore only $\omega_6 = 1$ and $\omega_5 = 1$. Remaining bit coefficients of the ω_m, $m = 1,2,3,4$ are equal to the zero: $3 = (000011)_2$. In this case the third-order WF is given by

$$W(3,\beta_2) = (-1)^{(\omega_5 \oplus \omega_4)\beta_2} = (-1)^{(1\oplus 0)\beta_2} = (-1)^{\beta_2} \quad (8)$$

The argument, β_k changes depending on normalized time of T=0.02sec. as shown in the Fig.4. Fig.5 depicts the β_2 and third-order discrete WF.

To achieve the stated in the introduction objective we multiply both sides of (6) by (8) and sum the product terms over the $n = 0,1,2,..., N-1.$, that is

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\sum_{n=0}^{N-1} P(-1)^{\beta_2} - \frac{1}{N}\sum_{n=0}^{N-1} P\cos(4\pi n/N)(-1)^{\beta_2} - \frac{1}{N}\sum_{n=0}^{N-1} Q\sin(4\pi n/N)(-)^{\beta_2} \quad (9)$$

Since the $(-1)^{\beta_2}$ is periodic and $\cos(4\pi n/N)$ is orthogonal with the $(-1)^{\beta_2}$ over the $n = 0,1,2,..., N-1$, the first and second terms on the right side of (9) vanish. Thereby, the (9) is rewritten as

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = -\sum_{n=0}^{N-1} Q\sin(4\pi n/N)(-)^{\beta_2} \quad (10)$$

As can be seen from Fig5, third order discrete WF with the normalized period of T has the discrete values defined as:

$$(-1)^{\beta_2} = \begin{cases} +1, \text{ at the intervals of } [0,N/4) \text{and} [N/2,3N/4] \\ -1, \text{ at the intervals of } [N/4,N/2) \text{and} [3N/4,N-1] \end{cases}$$

So Eq (10) can be written as

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\left[\sum_{n=0}^{N/4-1} Q\sin\left(\frac{4\pi}{N}n\right) - \sum_{n=N/4}^{N/2-1} Q\sin\left(\frac{4\pi}{N}n\right) + \sum_{N/2}^{3N/4-1} Q\sin\left(\frac{4\pi}{N}n\right) - \sum_{n=3N/4}^{N-1} Q\sin\left(\frac{4\pi}{N}n\right)\right. \quad (11)$$

The analysis indicated in Fig.3 and 5 intervals shows that the function of $\sin(4\pi n/N)$ has negative values at the intervals of *[N/4, N/2-1]* and *[3N/4, N-1]*, then the Eq. (11) simplifies to

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\sum_{n=0}^{N-1}\left|Q\sin\left(\frac{4\pi}{N}n\right)\right| \quad (12)$$

Since

$$\frac{1}{N}\sum_{n=0}^{N-1}\left|Q\sin\left(\frac{4\pi}{N}n\right)\right| = Q,$$

Eq (12) defines the RP over the period of T

$$Q = \frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} \quad (13)$$

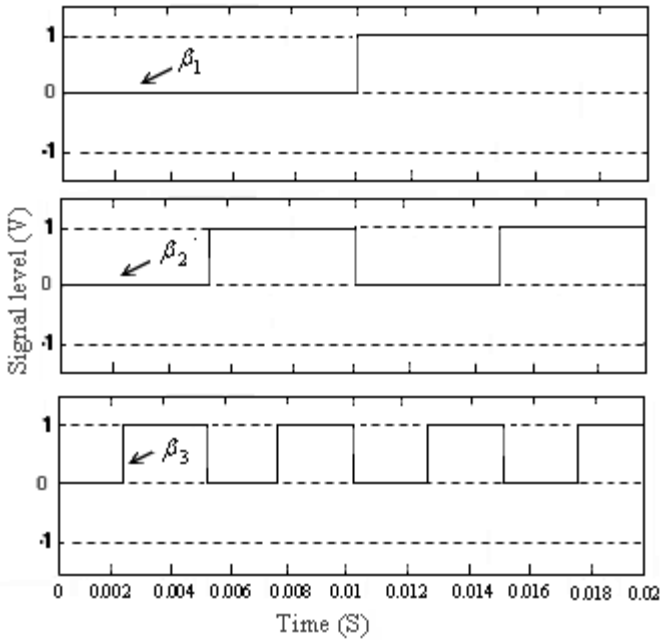

Fig.4. Time representation of final three bit coefficients of the binary representation of β_k

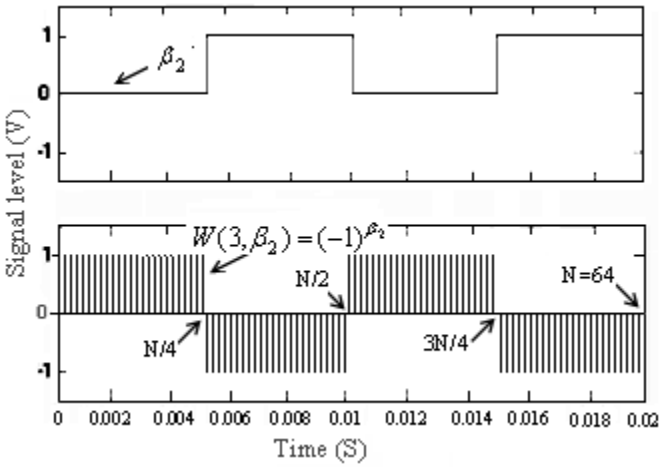

Fig.5. Time representation of β_2 and third-order discrete WF

III. DESIGN OF ELECTRONIC REACTIVE POWER METER

The block diagram of electronic RP meter is shown in the Fig.6. The voltage and current signals are fed to the inputs of the analog multiplier (AD633), which produces time continuous output waveform which is proportional to the product of the input voltage and current signals, i.e. instantaneous power $p(t)$ defined by (1). Output waveform of AD633 is diagramed in the Fig.7a. The output of AD633 is fed to the analog-to- digital converter (ADC0804) controlled by the control logic (CL). The ADC0804 converts the input signal $p(t)$ to the output digital data samples $p(n)$ from each output signal of the digital sampler (DS). The digital samples $p(n)$ defined by (6) are shown in the Fig.7a. The sampled signals are formed from input voltage signal $u(t)$ to achieve

the frequency insensitive measurement. The output signals of the DS are shown in the Fig.7b. The output from the ADC0804 is fed to the inputs of the up-down counter (UDC) through the multiplexer. The multiplexer is used to connect the output of the ADC0804 to either the up input or the down input of the UDC in accordance with the (11). First and third quarter part of the $p(n)$,

$i = 1,2,3,4,5,6,7,8,17,18,19,20,21,22,23,24$ (See Fig.8a) are entered to the up input and the second and the forth quarter parts of the $p(n)$,

$i = 9,10,11,12,13,14,15,16,25,26,27,28,29,30,31,32$ (Fig.8b) are entered to the down input of the UDC. So in accordance with (11) the remainder number in the UDC to the end of the second period of the input signal becomes equal to the RP of the investigated circuit. The UDC binary output is indicated in the display.

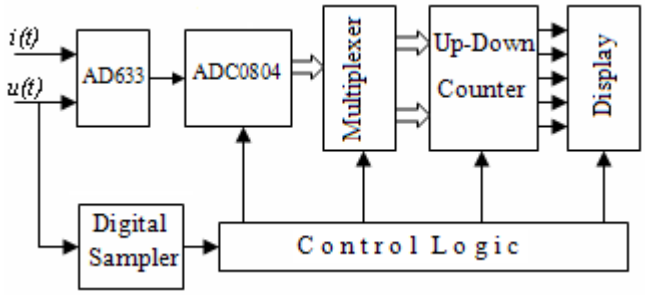

Fig.6. Block diagram of electronic powermeter

IV. DIGITAL SAMPLER

The important component of the proposed electronic RP meter providing the independence of the measurement results from the change of input signal frequency is the DS. DS produces sampling signals with the predetermined frequency. Moreover, sampling frequency is correlated with the frequency of the input signal to be measured.

The block diagram of the DS is represented in the Fig.9. A zero crossing detector produces the pulses when input voltage signal $u(t)$ crosses the zero level. As seen from Fig.7, the duration of this impulses becomes the half (T/2) of the full period T of the input voltage signal $u(t)$. During this first period of T the CL enables the output impulses of the clock to be passed through the binary ripple counter (BRC) only to the input of the binary storage counter1.

The counter capacity of the BRC is defined in accordance with the demand to the sampling rate of the instantaneous power signal $p(t)$.

The number of impulses stored in the binary storage counter1 to the end of time interval of T is given by,

$$M = (f_c T)/N \tag{14}$$

Where, f_s is the clock frequency and N is the counter capacity of the BRC ($N = 2^m$, m is the number of bits).

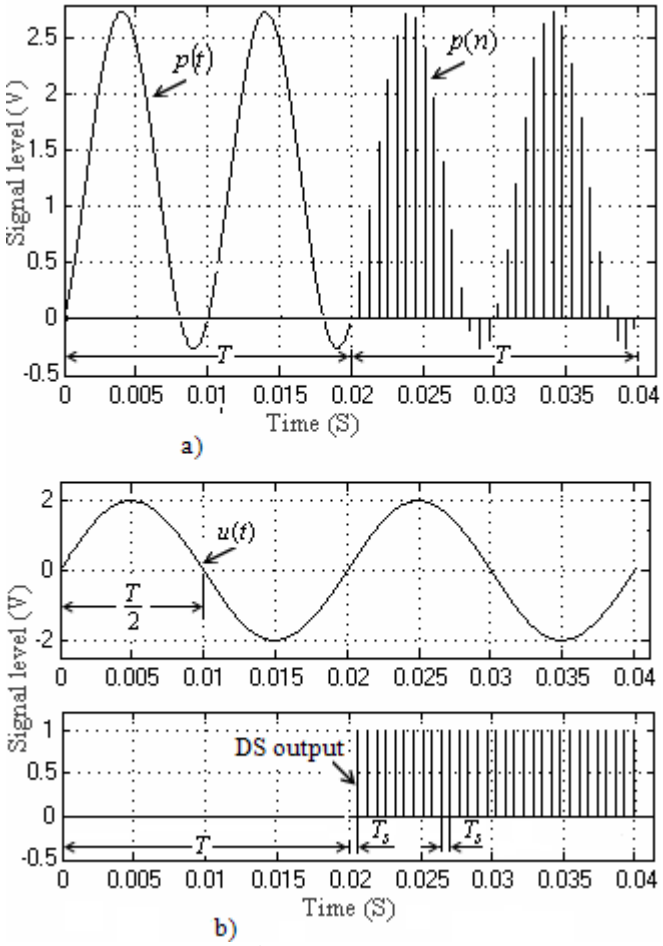

Fig.7. Output waveforms: a) analog multiplier and ADC; b) input $u(t)$ and DS output signals.

Note that, N is defined from Shannon criterion on sampling frequency At the beginning of the second period T of $u(t)$ the CL enables the output impulses of the clock to be passed only to the input of the second binary storage counter2. When the number of the clock impulses stored in the second binary storage counter becomes equal to the M, i.e. the number, stored in the first BSC1 the code comparator (CC) produces its first output impulse. This impulse resets the BSC2 to zero and becomes the first output impulse of the DS (Fig.7). Since the clock pulses continue to enter to the input of BSC2 continuously during second full period of T (Fig.7). When the number of impulses counted by the BSC2 becomes again equal to the M, the CC produces the second output impulse of the DS resetting the BSC2 to zero.

The time interval between the instant of BSC2 was reset to zero and the time instant of BSC2 has counted M number of impulses is given by

$$T_s = f_c / M \tag{15}$$

Where T_s is the sampling interval (See Fig.7) and $f_s = 1/T_s$ is the sampling frequency. Substitution (15) into (16) gives the expression relating sampling interval T_s to the input signal period T:

$$T_s = T/k \tag{16}$$

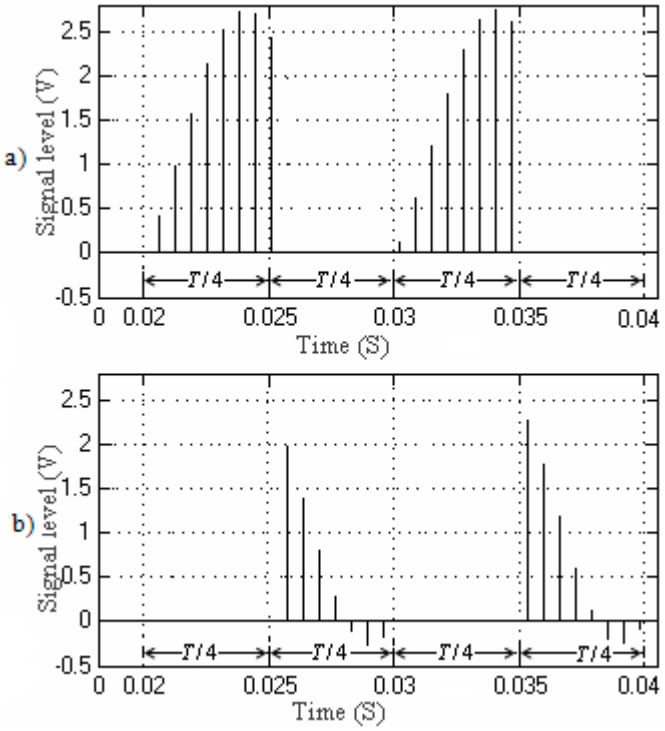

Fig.8. Sampled power signal $p(n)$: a) first and third quarter part; b) second and forth quarter part.

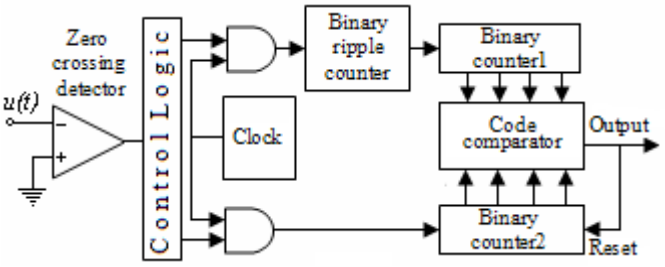

Fig.9. Digital sampler

So repetition interval of the DS output impulses is the k times less the T . This relationship can also be written in terms of the DS input and output frequencies:

$$f_s = kf \tag{17}$$

It is evident from (15) and (19) that, the number of collected data N do not depend on the input signal frequency; consequently measurement results are also independent on the input signal frequency.

Carefully look at derived expressions of (15) and (16) allows to state that designed electronic meter meets the requirement of coherent data acquisition and thereby is the good solution for the preventing of the energy leaking from spectral components [6] when input signal frequency f is to vary because of the power distribution system instability. Thus, sampling period T_s becomes the function of the being sampled input signal period T . Proposed approach to DS implementation provides coherent data acquisition as a result avoids the spectral leakage in the comparatively wide range deviations of the power frequency in the investigated circuit. Thus an extreme requirement on different algorithmic and hardware solutions to achieve the coherent sampling while dealing with the sampled data is avoided.

V. Simulation Results

The simulation circuit of the proposed novel analog signal processing (ASP) structure for evaluation of RP and active power from instantaneous power $p(t)$ is shown in Fig.10. The simulation circuit includes: voltage source, $u(t)$; current source, $i(t)$; multiplier, which produces, the instantaneous power $p(t) = u(t)i(t)$; zero- and third-order Walsh code generators; the pair of multipliers for obtaining the products of the zero-and third-order WFs by $p(t)$; integrating analog-to-digital converters ADC1 and ADC2 used to produce digital codes proportional to the evaluated values of the active and the reactive components of the EP, respectively. During experimental studying the input voltage, $u(t)$ and the current, $i(t)$ signals were taken as [14-16].

$$u(t) = U_m \sin(\omega t) \text{ and } i(t) = I_m \sin(\omega t - \varphi) ,$$

where I_m =2A, U_m =4V, $\omega = 2\pi f$, f = 50 is the linear frequency in Hz, ω =314 is frequency in rad/sec, φ -phase shift between the voltage $u(t)$ and the current $i(t)$ signals. The phase shift, φ between the voltage $u(t)$ and the current $i(t)$ signals has been varied in the interval of $\varphi = 0 - 90°$. The signal proportional to the instant value of the power $p(t)$ which is applied to the first inputs of the pair of multipliers is given by,

$$p(t) = 8\sin(314t) * \sin(314t - \varphi)$$

The time representation of the signals $p(t)$ and $p(t) * Wal(3, \beta_k)$ are shown in the Fig.11. The signals $p(t)$ and $p(t) * Wal(3, \beta_k)$ are integrated and converted to

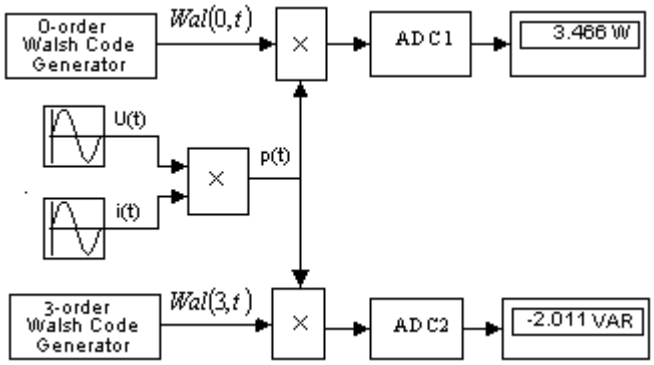

Fig.10. Proposed ASP technique based structure for the active and reactive power evaluation

digital form using the ADC1 and ADC2, respectively. The digital codes, generated by ADC1 and ADC2 represent

resulting evaluated values of the active and the reactive components of the electrical power (Fig.10). The results of the experimental verification are represented on the Table 1.

From the Fig.12 it can be seen the error appearing because of the change of the phase shift φ in the interval of from 0 to 90°.

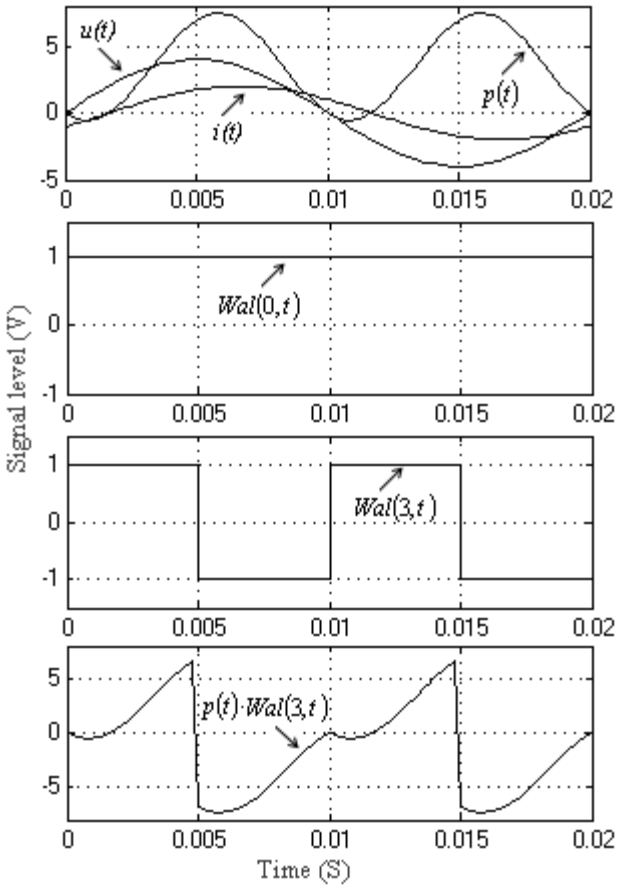

Fig.11. The Components outputs signals versus time representation

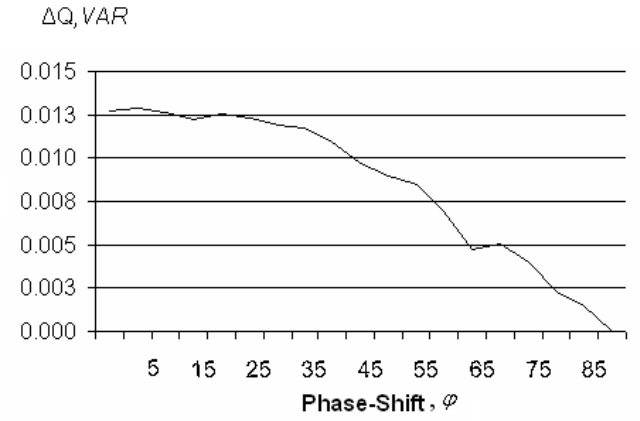

Fig.12. Relation between the measurement error ΔQ and the phase-shift rate φ.

The essential advantage of the proposed method for evaluation of RP has been verified by experimental studies. One of these advantages is that in contrast to the known existing methods the proposed method does not require a phase shift of the current signal to the $\pi/2$ with respect to the voltage signal. The phase shift operation requires the corresponding hardwire which may result in the additional measurement error. The author is currently working towards the estimation and correction of harmonic distortions influence on proposed RP evaluation method.

TABLE I
SIMULATION RESULTS OF THE RP EVALUATION ALGORITHM

		Results of calculating		Outputs of the simulation circuit		Percentage error
	φ	P,W	Q,VAR	P,W	Q,VAR	δ
0	0	4,000	0,000	4,002	-0,0127	100
1	5	3,985	-0,348	3,987	-0,3613	3,558
2	10	3,939	-0,694	3,941	-0,7069	1,790
3	15	3,864	-1,035	3,866	-1,047	1,169
4	20	3,759	-1,367	3,761	-1,38	0,912
5	25	3,626	-1,690	3,627	-1,702	0,724
6	30	3,465	-1,999	3,466	-2,011	0,593
7	35	3,277	-2,293	3,278	-2,305	0,508
8	40	3,065	-2,570	3,066	-2,581	0,424
9	45	2,830	-2,827	2,83	-2,837	0,342
10	50	2,573	-3,063	2,572	-3,072	0,292
11	55	2,296	-3,275	2,296	-3,284	0,259
12	60	2,002	-3,463	2,002	-3,47	0,201
13	65	1,693	-3,624	1,693	-3,629	0,131
14	70	1,370	-3,758	1,368	-3,763	0,135
15	75	1,038	-3,863	1,036	-3,867	0,103
16	80	0,697	-3,939	0,696	-3,941	0,057
17	85	0,352	-3,985	0,3469	-3,986	0,037
18	90	0,003	-4,000	0,0008	-4,0000	0,000

VI. CONCLUSION

The evaluation of reactive component of EP with application of a WF simplifies the volume of computing operations on some order in comparison with sets of algorithms based on decomposition of signals on harmonics (trigonometric components). Evaluation of RP using WF results in certain advantages:

a) During the processing of the signals on the base of WF time-shifting of the signals acts on the structure of the signals. This influence becomes useful during the evaluation of the power components allowing the obtaining extra knowledge concerning the phase-shifts on the harmonics of the input signals;

b) The requirement of IEEE/IEC definition of a phase shift of $\pi/2$ between the voltage and the current signals, typical for reactive power evaluation, is eliminated from signal processing operation;

c) The RP is evaluated without the phase-shift operation between the voltage and current waveforms to achieve increased efficiency of computational operations and hardware implementation;

d) During DSP the multiplication of the sample values of the signals by corresponding order WF is performed simply, by alteration of sign of the signal samples from +1 to -1 only during even quarters of the input signal periods.

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REFERENCES

[1] Branislav Djokic, Eddy So, and Petar Bosnjakovic. "A High Performance Frequency Insensitive Quadrature Phase Shifter and Its Application in Reactive Power Measurements", *IEEE Trans. Instrum. Meas.*,Vol. 49, February 2000, pp.161-165.

[2] W.-K. Yoon and M.J. Devaney. "Reactive Power Measurement Usinq the Wavelet Transform", *IEEE Trans. Instrum. Meas.*,Vol. 49, April 2000, pp.246-252.

[3] S.L.Toral, J.M.Quero and L.G.Franquelo. "Reactive power and energy measurement in the frequency domain using random pulse arithmetic", *IEE Proc.-Sci. Technol.*, Vol. 148, No. 2, March 2001, pp.63-67.

[4] T.W.S.Chow and Y.F.Yam. "Measurement and evaluation of instantaneous reactive power using neural networks", *IEEE Transactions on Power Delivery*, Vol. 9, No. 3, July 1994, pp.1253-1260.

[5] A. Ozdemir and A. Ferikoglu. " Low cost mixed-signal microcontroller based power measurement technique", *IEE Proc.-Sci. Meas. Technol.*, Vol. 151, No. 4, July 2004, pp.253-258.

[6] A. Brandolini, A. Gandelli, F. Veroni, "Energy meter testing based on Walsh transform algorithms", *Instrumentation and Measurement Technology Conference*, 1994. Conference roceedings, Vol.3, 10-12 May 1994, pp.1317-1320,

[7] Bai liyun, Wen biyang, Shen wei, and Wan xianrong. "Sample rate conversion using Walsh-transform for radar receiver", *Microwave Conference Proceedings*, 2005. APMC 2005. Asia-Pacific Conference Proceedings.Volume 1, 4-7 Dec. 2005.

[8] IEEE Std. 1459-2000, "IEEE Trial Use Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Non-Sinusoidal, Balanced, or Unbalanced Conditions", Institute of Electrical and Electronics Engineers / 01-May-2000 / 52 pages.

[9] Trachtman A.M., Trachtman V.A. *Fundamentals of the discrete signals' theory on the finite intervals*. - M.: Sov. Radio, 1975. -208 p.

[10] A.N. Abiyev, "A new signal processing technique for measurement of the reactive power in the power transmission and distribution systems", Southeastcon 2009, IEEE, Hantsville, AL, USA, pp.356-361.

[11] A.N. Abiyev, "A new electronic reactive power meter based on Walsh Transform algorithms", IEEE Transmission and Distribution Conference and Exposition, 2009 (T&D. IEEE/PES). Chicago, IL, USA, pp. 1-7.

[12] A.N. Abiyev, "A New Signal Processing based Method for Reactive Power Measurements", *Journal Of Computers*, Vol. 4, No. 7, pp.623-630, [doi:10.4304/jcp.4.7.623-630].

[13] P. Carbone and D. Petri, "Average power estimation under nonsinusoidal conditions", *IEEE Trans. Instrum. Meas.*, Vol. 49, No 2, Apr. 2000, pp. 333–336.

[14] A.N.Abiyev, I.M. Aliyev, "An Electric Power Measurement Based On Discrete Walsh Transformation", Proceedings of the International Conference *Interactive Systems: The Problems Of Human-Computer Interaction*, 23-27 September 2003, Ulyanovsk, Russia, pp.195-196.

[15] A.N. Abiyev, "The Walsh Function Based Electric Power Measuring Method", Proceedings of the *3rd International Symposium on Electrical, Electronics, and Computer Engineering*, November 23-25, 2006. Nicosia, North Cyprus, pp.177-181.

[16] A.N. Abiyev, "Frequency Insensitive Digital Sampler and Its Application to the Electronic Reactive Power Meter", In: Tarek, S. (Ed.), Advances in Computer and Information Sciences and Engineering. Publisher: Springer Netherlands, Netherlands, 2008, pp. 21-26.

BIOGRAPHIES

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A Local Optimization Technique for Assigning New Targets to the Planned Routes of Unmanned Aerial Vehicles

M. Karakaya

***Abstract*— Using Unmanned Aerial Vehicles (UAVs) for reconnaissance purposes requires dynamic route planning. For example, when some of the UAVs are lost or new targets pops up during the mission, routes of each UAV should be re-arranged accordingly. This article proposes an iterative local optimization for the distribution of new targets to the existing routes in such circumstances. The proposed iterative insertion algorithm basically executes in phases. In the first phase of the algorithm, a selected UAV's route is updated by trying to insert new targets if possible. In the second phase, a 2-opt technique is applied to the modified UAV routes for minimizing the route distance. After the second phase, if there remains some uncovered targets we begin to run the first phase again. The proposed algorithm will terminate either all the new targets are covered or 2-opt technique does not produce any better route distances. The simulation results of the iterative insertion algorithm show the effectiveness and the success of the proposed algorithm.**

Index Terms— **UAV, dynamic route planning, target assignment, iterative insertion algorithm,**

I. Introduction

USING Unmanned Aerial Vehicles (UAVs) are one of the reconnaissance methods gaining popularity recently [1, 2, 3]. Since UAVs are very expensive and scare resources, UAV route planning is vital for increasing their effectiveness in monitoring targets [4]. Route planning can be static or dynamic [1, 5]. In static route planning, routes are constructed according to given UAVs and targets and do not change during the mission. However, in dynamic route planning, number of routes or UAVs can alter which requires the update of existing routes to adopt these changes. For example, some of the UAVs can be lost during the mission or new targets might pop up after the take-off.

In this work, we deal with dynamic route planning. We assume that we are given an initial list of targets and UAVs with a fixed flight range. Using Nearest Neighbor (NN) heuristic we create the initial route for each UAV. Then, new targets pop up and the routes are to be changed. One important consideration of the updating route can be the fact that we would not like to change the whole route, that is, create routes from scratch, due to several practical issues. Instead, we would like to update the existing routes by allocating new targets to the existing routes properly. Using this motivation we propose an iterative heuristic to update the existing routes with new targets. The proposed algorithm aims to cover maximum number of new targets as well.

Paper is organized as follows. In the following section we present the Iterative Insertion Algorithm (IIA) in details. The simulation model and the results of the experiments are summarized in Section 3. Then we concluded the work in Section 4.

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II. Iterative Insertion Algorithm

This article proposes an iterative local optimization for the distribution of new targets to the existing routes in dynamic route planning. In the proposed solution, it is supposed that all UAVs have the same flight ranges, their initial routes are planned, and they have already visited some of the targets according to these routes. Furthermore, for each UAV, the slack range which is the difference between the flight range and initial route distance is calculated.

Whenever some new targets appear, the proposed Iterative Insertion Algorithm executes as follows. In the first phase of the algorithm, an UAV with the highest slack value is picked and its route is modified by deleting a target whose deletion cause a maximum increase in the slack value. This target is appended to the end of the new target list. Then, we attempt to insert a new target to that UAV's route at a time. Adding a new target to an existing route causes an increase in the route distance, which is called update cost. If the update cost is not greater than the slack range, the new target is inserted to the route. After testing the insertion of the new target to any location in the existing route, we select the location which cause minimum update cost. The target is inserted to this location in the route list.

After finishing attempts with all new targets, if any of them is left over, insertion process is executed with the UAV having the next highest slack range as described above until either all UAVs or new targets are finished. If there are still uncovered

new targets after trying all UAVs, the algorithm proceeds the second phase in which a 2-opt technique is applied to the modified UAV routes for increasing the slack ranges. Then, the first phase of the algorithm is re-run for the remaining uncovered targets. Algorithm will terminate either all the targets are covered or the 2-opt technique does not produce any better slack value.

III. Simulation Model And Experiment Results

The proposed algorithm is implemented using Mason simulation library [7] and tested with various experiments for different parameter settings and TSP data files [6]. The preliminary results show the effectiveness and the success of the proposed iterative insertion algorithm.

A. Simulation Model

We assume that targets locations are given in the selected TSP file. We first randomly select a base location among these targets so that all UAVs are located on this location. Then according to the specified initial target number (ITN), target locations are chosen and the initial routes for all UAVs to cover these targets are generated using Nearest Neighbor (NN) heuristic. Then, the rest of the TSP file is used as the new target list.

To cover the new targets, we apply the proposed iterative insertion algorithm (IIA). To evaluate the result of the proposed heuristic, we also run NN heuristic to create new UAV routes for all the targets.

For each set of experiments we run the simulation 40 times and get the averages of the observed results.

As a performance metric, we select to count the number of targets in the routes created by any algorithm. First, for the given Initial Target Number (ITN) we randomly select targets as the initial targets. We create the first routing using the NN heuristic. The number of targets in this routing is called TN_{INN}. We assume that new targets pop up as the number of Pop-Up Target Number (PTN). For covering these new targets we first apply the NN heuristic from scratch. The recalculated routing plan consists of TNRNN number of targets. Then as a last step, we apply the proposed Iterative Insertion Algorithm (IIA) on the initial routing and create a new routing plan which has TNIIA number of targets. The success of the IIA is defined as in Eq. (1).

$$\text{Success} = \frac{\text{TN}_{\text{IIA}} - \text{TN}_{\text{RNN}}}{\text{TN}_{\text{RNN}}} * 100 \quad (1)$$

B. Experiment Results

In these experiments, we use CH130.tsp file that has 130 coordinates which are used for the target and base locations. TABLE I summarizes the target numbers that are covered by the planned routes when 2 UAVs are employed with a fixed Flight Range 1500 meters. The IIA successfully plans more targets to be visited by the UAVs for different initial target numbers compared to the NN heuristic. For example, when 40 new targets are pop up IHH can route about 57 targets while NN can route about 53 targets on the average. In this table we observe that as the new target number gets less, the success decreases as well. This is probably due to the fact that there is less room to optimize the solution since we have fewer new targets to insert into the existed initial NN routes.

TABLE I
NUMBER OF TARGETS COVERED BY THE HEURISTICS WHEN 2 UAVS WITH FLIGHT RANGE = 1500 ARE USED

ITN	PTN	#UAV	TN_{RNN}	TN_{IIA}	Success (%)
70	*60*	*2*	*52.90*	*58.47*	*11*
90	*40*	*2*	*52.70*	*56.89*	*08*
110	*20*	*2*	*53.37*	*57.32*	*07*

As a second experiment, we change the number of UAVs. In TABLE II, we observe that the IIA generates better results for different number of UAVs. However, as the number of UAVs is increased the success ratio is decreased.

TABLE III
NUMBER OF TARGETS COVERED BY THE HEURISTICS WHEN DIFFERENT NUMBER OF UAVS WITH FLIGHT RANGE = 1500 ARE USED

ITN	PTN	#UAV	TN_{RNN}	TN_{IIA}	Success (%)
70	*60*	*2*	*52.90*	*58.47*	*11*
90	*60*	*4*	*72.68*	*79.15*	*09*
110	*60*	*4*	*89.87*	*94.74*	*05*

To observe the change in the initial routing while covering the new targets we provided the figures below. As discussed above, we can opt for a least difference in the existing UAV routes while appending new targets. In the figures the base is marked with a square, and targets as circles. In Fig. 1, we see the initial NN route created for the initial targets and new targets. Fig. 2 shows the routing of recalculated NN heuristic and the updated initial NN routing by the proposed IIA. As seen in the figures, the proposed IIA causes fewer changes in the existing initial UAV routings compared to the result of the recalculated route. Thus, we can argue that the proposed heuristics can generate new routings for the UAVs with more targets covered and with fewer changes occur in the existing routes. For this specific example, TN_{INN} is 44, TN_{RNN} is 52, and TN_{IIA} is 59.

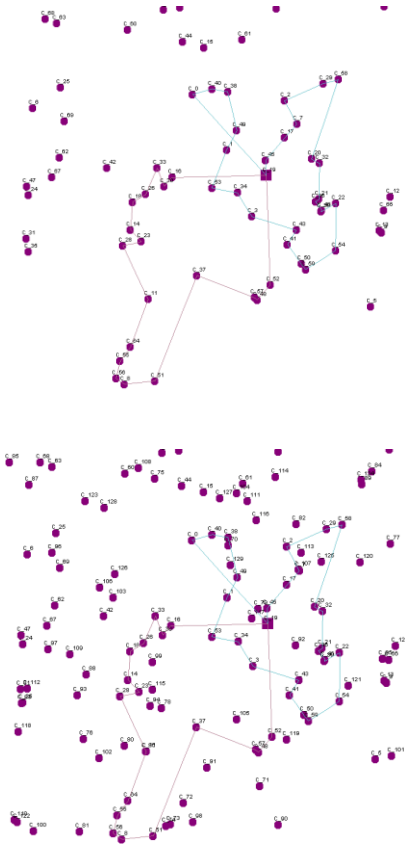

Fig. 1. (on the top) the initial NN route for the initial targets and (on the bottom) the pop-up targets

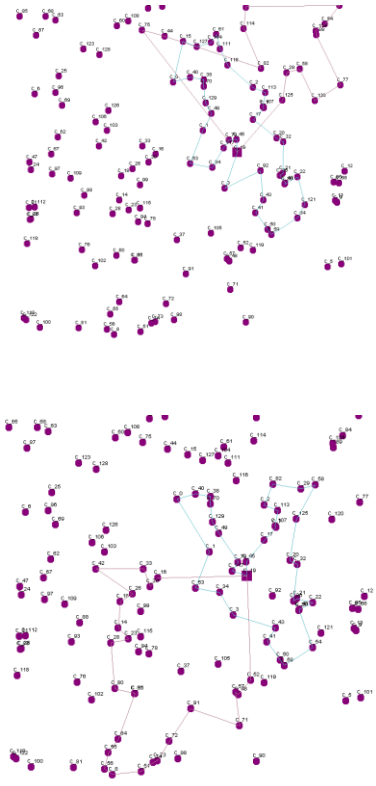

Fig. 2. (on the top) the recalculated NN route for the new targets whereas (on the bottom) the route created by the proposed IIA

IV. CONCLUSION

In this work, we attack the problem of dynamic route planning by designing an iterative insertion algorithm. We compare the results of the initial experiments and have observed encouraging advantage of the proposed heuristic over the NN heuristic. As a future work, we aim to extend our work by introducing more comprehensive performance metrics and conducting the experiments with different TSP files.

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REFERENCES

[1] Ercan, C., Gencer, C. (2013). Dinamik İnsansız Hava Sistemleri Rota Planlaması Literatür Araştırması ve İnsansız Hava Sistemleri Çalışma Alanları. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, 19(2), 104-111.

[2] Glade, D. (2000). Unmanned Aerial Vehicles: Implications For Military Operations. Air University Press Maxwell Afb Al.

[3] Everaerts, J. (2008). The Use Of Unmanned Aerial Vehicles (Uavs) For Remote Sensing And Mapping. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37, 1187-1192.

[4] Ergezer, H., Leblebicioglu, K. (2012). Path Planning For Multiple Unmanned Aerial Vehicles. In Signal Processing and Communications Applications Conference (SIU), 2012 20th (pp. 1-4). IEEE.

[5] , J. J., Arévalo, O., Pajares, G., De La Cruz, J. M. (2009). UAV Trajectory Planning For Static And Dynamic Environments. Aerial Vehicles, in Tech, 581-600.

[6] TSPLIB, 1995, TSPLIB, [WWW document; retrieved August 2013] URL http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/.

[7] Luke, S., Balan, G. C., Panait, L., Cioffi-Revilla, C., & Paus, S. (2003). MASON: A Java multi-agent simulation library. In Proceedings of Agent 2003 Conference on Challenges in Social Simulation (Vol. 9).

BIOGRAPHIES

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TRIZ: Theory of Inventive Problem Solving and Comparison of TRIZ with the other Problem Solving Techniques

B. Cerit, G. Küçükyazıcı, and D. Şener

***Abstract*— In today's business world, it is obligatory to produce or closely follow and apply the technological and scientific developments in order to survive in a highly competitive environment by establishing productive, efficient and profitable businesses and to keep abreast of the rapid changes of the needs. In this paper, TRIZ's (Theory of Inventive Problem Solving) difference, which occurred with the possession of inventive problem solving philosophy and the provision of the possibility to use extensive knowledge base, is explained. The systematic approach of TRIZ is essentially emphasized in detail. Brief explanations of other problem solving methods are also presented in order to provide a benchmark to reveal the strong and weak characteristics of TRIZ among the other methods. The possibility of using TRIZ together with other problem solving techniques, instead of using the method as a single solution provider, is discussed in the paper.**

Index Terms—**TRIZ, Problem Solving Techniques, Management**

I. Introduction

IN today's business world, it is obligatory to produce or closely follow and apply the technological and scientific developments in order to survive in a highly competitive environment by establishing productive, efficient and profitable businesses and to keep abreast of the rapid changes of the needs. Products, services and related processes, which have to be developed and differentiated continuously, create technical and non-technical problems, which become gradually more difficult. Inventive and innovative point of view is necessary to solve these problems which cannot be handled by traditional methods. In the beginning of 1946, G. Altshuller wanted to facilitate the resolution of difficult inventive problems and to provide this facilitation to all humanity, and developed TRIZ (Theory of Inventive Problem Solving) so as to provide a tool for this necessity. In this paper, TRIZ's difference, which occurred with the possession of inventive problem solving philosophy and the provision of the possibility to use extensive knowledge base, is explained. The systematic approach of TRIZ is essentially emphasized in detail. Brief explanations of other problem solving methods are also presented in order to provide a benchmark to reveal the strong and weak characteristics of TRIZ among the other methods. The possibility of using TRIZ together with other problem solving techniques, instead of using the method as a single solution provider, is discussed in the paper. The contribution of TRIZ to future Industrial Engineering applications is also considered.

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II. Innovation and Innovativeness Concept

Innovation concept which is defined in different ways by various resources can be described as making new ideas, products, services and applications which are planned to be usable available. According to Drucker, innovation is the change of products and services in a way that can adapt to rapidly changing markets. In 1995, with respect to Money, Loan and Coordination Committee's resolution aiming to support research and development projects in Turkey, innovation is described as conversion of an idea into a marketable new or an improved product or an advanced method used for production of goods and services [1].

Innovation which is whether offered on the basis of technological possibilities or required on the basis of social needs and market requirements is a highly debated issue. Marquis indicates that "the recognition of the demand is more common factor than the recognition of technical potential in a successful innovation" [2].

Such examples that companies such as Sony, Motorola, Hewlett Packard have succeeded to elicit 30% of income thanks to their innovative strategies in a two-year period and that Sony has provided approximately 50 new products into the market every year reveals the importance of the invention of new products with smaller sources and making innovation to the existing products [3]. In this context, businesses looking for innovative solutions to problems are found to constitute the competitive section of the market.

III. Problem Solving

There are two groups of problems people face: those with generally known solutions and those with unknown solutions.

Those with known solutions can usually be solved by information found in books, technical journals, or with subject matter experts. The other type of problem requiring creativity/innovation and containing contradiction is one with no known solution and thus called "an inventive problem" [4].

3.1. Traditional Approaches to Problem Solving

Traditional Approaches to Problem Solving are as Trial and Error Method, Psychological Inertia, Brainstorming, Morphological Analysis, Synectics, Pareto Analysis, Distribution Diagrams, Control Charts, Cause-and-Effect Diagrams, Histograms, and Poka-Yoke (Mistake-proofing) Analysis

3.2. Inventive Approaches to Problem Solving

Inventive Approaches to Problem Solving are Quality Function Deployment, Taguchi methods, Six Sigma Methodology, Failure Mode and Effects Analysis (FMEA), and Design of Experiment.

IV. TRIZ: THEORY OF INVENTIVE PROBLEM SOLVING

4.1. Inventive thinking and inventive problems

An inventive problem is a problem that contains at least one contradiction. A contradiction is a situation where an attempt to improve one feature of a system leads to the degradation of another feature. The conventional way to deal with a contradiction is to look for some kind of compromise or trade-off. Problem types are shown in TABLE I [5].

TABLE I
PROBLEM TYPES [5]

New Knowledge (Scientific Problems)	New knowledge applied to known problems. Example: New plastics provide strong, lightweight products.	New knowledge applied to new problems. Example: Various uses for lasers (surgery, etc).
Existing Knowledge (Engineering Problems)	Existing knowledge applied to known problems. Example: All engineering tasks with generally known solutions.	Existing knowledge does not provide a satisfactory solution. **Inventive problem-- a new approach is needed.**
	Known Problem	New Problem

Inventive problems are often mistakenly considered to be the same as engineering, technological and design problems. However, that the inventor is looking for ways to solve problems by eliminating contradictions sets out the difference from the design process. When a creative solution or a concept found, the talents of engineers, technology manufacturers and designers need to be used [6].

The inventive thinking system is based on principles developed by the Russian scientist, Genrich Altschuler, who wanted to develop a thinking framework that would help arrive at unconventional solutions, and did not accept the concept of randomness. After studying five hundred thousand unconventional/inventive solutions and comparing them to the situation existing before the discovery of the solution, he reached the following conclusions [7]:

- Inventive solutions are based on overcoming contradictions.
- Inventive solutions are based on a finite number of methods.
- It is possible to find agreement between the different types of contradictions and arrive at the effective tactics to overcome them.

4.2. TRIZ: Theory of Inventive Problem Solving

In today's global market and ruthless competition, it has become difficult to create breakthrough products. Recently, "Innovative Engineering" era promising to improve significantly the ability to solve engineering problems that appear to be difficult and even impossible has begun. There is a revolutionary new technique which improves Engineer's knowledge, creativity and problem solving skills and enables him to attack difficult problems that require thinking .The name of this method is "TRIZ" [8]. TRIZ which is a Russian acronym consisting of initial letters of **T**eoriya **R**esheniya **I**zobreatatelskikh **Z**adatch means "Theory of Inventive Problem Solving". The theory is created and introduced to the world in 1946 by a Russian engineer Genrich Altshuller working in the patent office of the Soviet Navy.

On the basis of the theory, the question of how to make discoveries made Altshuller inquisitive. Upon this, he worked on 200,000 patents in various fields and proved that there are 1,500 technical contradictions which can be solved by applying the basic principles [9]. Altshuller examined patents in terms of inventive problems and how they were solved and indicated that only 40000 of solutions were truly pioneering inventions, the rest represented the use of previously known idea or concept but in a novel way. Thus, the conclusion was that an idea of a design solution to new problem might be already known. TRIZ, based on a systematic view of technological world, provides techniques and tools, which help designers to create a new design idea and avoid numerous trails and errors during a problem solving process [10].

The theory is built on the following three principles [6]:

1. Ideal design is the goal.
2. Contradictions help to solve the problems.
3. Innovative process can be configured systematically.

Figure 1 illustrates the basic structure of TRIZ. TRIZ analytical tools, which do not use every piece of information about the product where the problem resides, are used for problem modeling, analysis and transformation. The way they

generalize a specific situation is to represent a problem as either a contradiction, or a substance-field model, or just as a required function realization. ARIZ is such a sophisticated analytical tool that it integrates above three tools and other techniques [10].

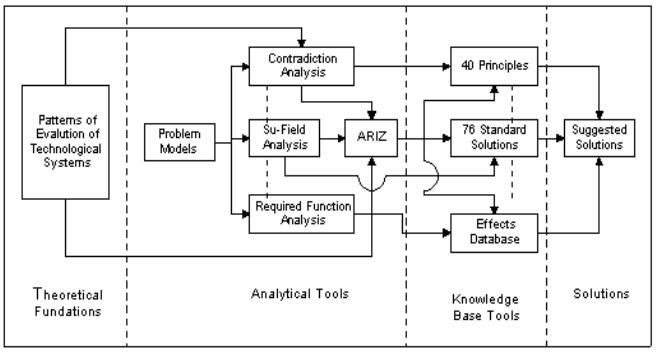

Fig 1. Structure of TRIZ Methodology [10]

As a result of work done on the different fields of engineering patents, a few important discoveries that make up the philosophy of TRIZ are as follows [11]:

- Each designer item is developed according to an order, which is common for all engineering fields and can be used to estimate development of the designed by using inventive problem solving.
- Design products are improved as a result of the destruction of several contradictions by means of the principles common to all fields of technology.
- As inventive problem is expressed as a contrast between the new requirements of the product needs of which are no longer met; inventive solution means elimination of contradiction in a state when compromise is not allowed.
- For the best possible solution, universal measure is idealism whose degree is the ratio between the beneficial effects of the product design, and expenditure of material, energy and information which is necessary to create these effects.
- Generally, in the search for a solution to the problem described as contradiction, the need for using physical knowledge which is not known by the engineer of the same field arises. To manage and direct physical effects of appropriate physical knowledge, indicators should be used. Physical phenomena are specified by the technical function lists in indicators.

Instead of walking around contradictions which is performed many times in the history of science and technology, the fundamental basis of TRIZ is to eliminate these contradictions. In TRIZ studies, by examining a large number of patents considered as records of technical innovations, typical solutions have been developed to the problems which hosted technical contradictions. Figure 2 illustrates that TRIZ produces better results on the contradiction parameters than normal design compromise does [12].

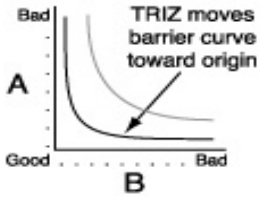

Fig 2. TRIZ's impact on contradictions [12]

TRIZ recognizes two categories of contradictions which are defined in Figure 2 [13]:

- **Technical contradictions:** Technical contradictions are the classical engineering trade-offs. The desired state can't be reached because something else in the system prevents it. In other words, when something gets better, something else gets worse. The examples below can be accepted as technical contradictions:
  - The product gets stronger , but the weight increases
  - The bandwidth for a communication system increases, but requires more power.
  - Service is customized to each customer, but the service delivery system gets complicated.
  - A car airbag needs to be opened quickly to protect the passenger but increasing the speed may lead to personal injury or even death for young children or those who improperly sit.
- **Physical contradictions:** Physical contradictions are situations in which one object has opposite requirements. That the system in problem is requested toward a direction in one aspect, while the same system is requested toward the opposite direction in the same aspect leads to physical contradiction. At this point, this situation is thought to be impossible [14]. Examples for Physical contradictions are stated below:
  - Surveillance aircraft should fly fast to get to the destination, but should fly slowly to collect data directly over the target for long time periods.
  - Software should be complex to have many features, but should be simple to be easy to use.
  - Coffee should be hot for enjoyable drinking, but cold to prevent burning the customer.
  - Training should take a long time, but not take any time.
  - A car airbag should be opened quickly and gently.
  - Chocolate-coated candy should be hot for easy filling, but should be cold to prevent melting.
  - Brake should be sudden to avoid accidents but should be gradual to ensure the control.

4.3. TRIZ's Problem-Solving Tools

4.3.1. Contradiction Analysis

Contradiction Analysis is a powerful tool of looking problem with the new perspective. In TRIZ standpoint, a challenging problem can be expressed as either a technical contradiction or a physical contradiction. A technical contradiction might be solved by using contradiction table that identifies 39 characteristics most frequently involved in design process. A physical contradiction might be solved by separation principles. Contradiction analysis is the fundamental step to apply 40 inventive principles, one of the knowledge base tools [10].

First of all, in order to express the technical problem, which aspect of the current system is intended to improve and which aspect of the system that contradicts with this improvement leads to worsening should be stated. To explain these aspects, TRIZ uses 39 standard parameters [12]. Moving objects in the system are defined as the objects which can easily change position in space, either on their own, or as a result of external forces. Vehicles and objects designed to be portable are the basic members of this class. Stationary objects in the system are defined as the objects which do not change position in space, either on their own, or as a result of external forces. The conditions under which the object is being used should be considered.

39 engineering parameters are listed below [15]:

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

To illustrate technical contradictions, a matrix consisting of 39 worsening and 39 improving parameters is used. Having analyzed the technological innovations registered in the patents, Altshuller and his students classifies every innovation problem in a 39x39-sized matrix. As the basis of solutions in the patterns is expressed according to 40 inventive principles, patent analysis is concluded by putting the first appropriate four principles in the cells of the matrix. This structure is named as "Contradiction Matrix". Contradiction Matrix has created the first information database of TRIZ.

Engineers eager to solve the technical problems should explain the offered problem in terms of improving parameter for worsening parameter and afterwards should use 40 most frequently used invention principles which are listed in the matrix in order to solve the problem inventively. Thus, in the process of problem-solving, engineers looking for a solution may take principles and practices as a reference.

"Contradiction Matrix" has presented a method that allows re-use of the previously realized innovations and the samples of big moves in order to solve the existing problems. However TRIZ, in order to achieve it, when identifying problems and solutions, has forced the use of the abstract framework of a fixed set of terminology by using the contradictions between 39 parameters for the problems and by using 40 parameters for the solutions. This enforcement has enabled to classify a very large number of patents and create an easily reusable knowledge. Figure 3 shows the usage of Contradiction Matrix eliminating the technical contradictions [12].

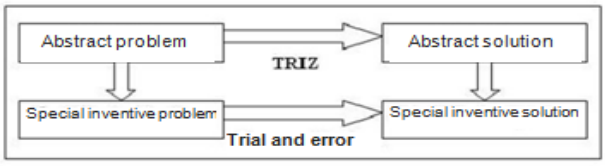

Fig 3. Contradiction Matrix eliminating the technical contradictions [12]

Being an easily-used toolkit of TRIZ, 40 inventive principals provide solutions simply and quickly [16]. These principals denote the 40 different strategies which have been derived from thousands of patent examinations and used for the solutions of the contradictions.

The 40 Inventive Principles with examples are listed and parts of a Contradiction Matrix are shown below [17]:

1. Segmentation
2. Taking out
3. Local Quality
4. Asymmetry
5. Merging

6. Universality
7. 'Nested doll'
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
11. Beforehand cushioning
12. Equipotentiality
13. 'The other way around'
14. Spheroidality
15. Dynamics
16. Partial or excessive actions
17. Another dimension
18. Mechanical vibration
19. Periodic action
20. Continuity of useful action
21. Skipping
22. 'Blessing in disguise'
23. Feedback
24. 'Intermediary'
25. Self-service
26. Copying
27. Cheap short-living
28. Mechanics substitution
29. Pneumatics and hydraulics
30. Flexible shells and thin films
31. Porous materials
32. Color changes
33. Homogeneity
34. Discarding and recovering
35. Parameter changes
36. Phase transitions
37. Thermal expansion
38. Strong oxidants
39. Inert atmosphere
40. Composite material

	Worsening Feature → / Improving Feature ↓	1 Weight of moving object	2 Weight of stationary object	3 Length of moving object	4 Length of stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	8 Volume of stationary object	9 Speed	10 Force (Intensity)	11 Stress or pressure
1	Weight of moving object	+		15, 8, 29,34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40
2	Weight of stationary object		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18
3	Length of moving object	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35
4	Length of stationary object		35, 28, 40, 29		+		17, 7, 10, 40		35, 8, 2,14		28, 10	1, 14, 35
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4		+		7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28
6	Area of stationary object		30, 2, 14, 18		26, 7, 9, 39		+				1, 18, 35, 36	10, 15, 36, 37
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17		+		29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37
8	Volume of stationary object		35, 10, 19, 14	19, 14	35, 8, 2, 14				+		2, 18, 37	24, 35
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34		+	13, 28, 15, 19	6, 18, 38, 40

Fig 4. Part of a Contradiction Matrix [17]

4.3.2. The Algorithm for Inventive Problem Solving (ARIZ)

With ideality law helping determine the direction of research and with technical analysis of conflict demonstrating obstacle to be destroyed, it is possible to control the process of creative problem solving. However, sometimes situations in which a contradiction hiding in the problem expression, and even not revealing by itself as an isolated case can be seen. At such times, since it is not easy to go to solution from the problem statement, intelligent tactics ensuring a step by step approach to the solution need to be used [18].

Being the acronym of the "The Algorithm for Inventive Problem Solving" in Russian language, ARIZ is presented as a method for implementing these tactics. According to Glenn Mazur, ARIZ is a systematic procedure for identifying solutions without apparent contradictions [4]. Depending on the nature of the problem, the number of phases to be completed varies and from an unclear technical problem, the underlying technical problem can be revealed thanks to ARIZ. ARIZ can be used with levels two, three, and four problems with respect to their inventive levels.

ARIZ whose structure is depicted in the Figure 5 is not an equation, but rather a multi-step process asking you a series of questions that integrates different pieces of TRIZ. ARIZ is a very "solution neutral" process; it takes preconceived solutions out of the problem statement.

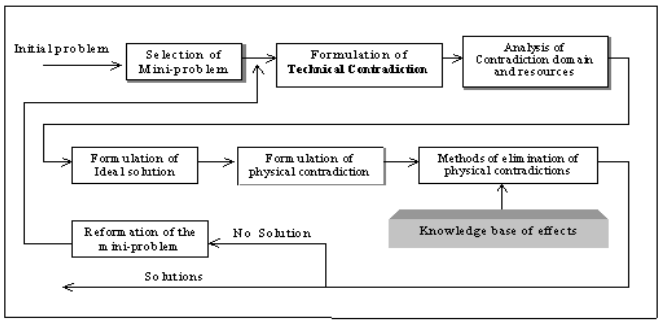

Fig 5. Structure of ARIZ [10]

ARIZ;

- is a process of problem reformulations.
- is a logical and disciplined period.
- continually reinterprets the problem.
- is the main TRIZ method for solving conflicts.

ARIZ utilizes the tools below which are within TRIZ scope in problem solving;

- Ideality for an understanding of the Ideal Solution to the problem Contradictions, by working first with the technical contradiction, then the physical contradiction,
- Resources of the system,
- Scientific effects,
- Substance-field modeling and Standard Solutions,
- the 40 Principles.

It is important to note that ARIZ is more than 50% problem reformulation. It is only through this guided reformulation that complex problems can be solved. ARIZ consists of a total of 9

basic steps that can be allocated into 3 main groups. The number of sub-steps varies from version to version of ARIZ [19].

TRIZ, has been constructed relying on a lot of sources. Among them there are sciences having a high degree of generalization such as dialectics, systems theory, cybernetics, information theory all of which have a very large area of application. Their current knowledge and new findings in the future can facilitate effectively the process of enlarging TRIZ on the path to creation of the general theory of creative problem solving.

There are two sides of human creativity: subjective (psychological) and objective. According to TRIZ, the essence of the issue is that only the person who grasps the objective laws of systems development and manages his/ her psychology along them can achieve a high efficiency in creativity. It is obvious that this management will be better if the person knows how his/her psychological factors work. So, teaching of enlarged TRIZ needs to be supplemented by more knowledge of cognitive psychology.

Patent information which on its merits is information about inventive creativity (or development of inventions) has helped research work in order to reveal the objective development laws of technological systems. Then, for the presentation of the enlarged TRIZ, in addition to the importance of using the laws of the evolution of systems for applications, illustrations taken from non-technological areas can be used.

When tackling inventive problems of the highest levels, in addition to knowledge of the technology studied on, extensive knowledge of geometry, physics and chemistry. In this context, the studies aiming to enable the inventors to have more information on these fields will gain importance in the future. In enlarging TRIZ, every enlargement in TRIZ should be verified, corrected and perfected through feedbacks established with the development information in general and patent information in particular and practices and the results of use of learners during and after the teaching process.

It's important for the enlargement of TRIZ to be reached not only higher levels of education but also people with low level of education. During its evolution and development period, TRIZ can be enlarged toward specialization on stages of a process of conducting creativity and innovation, and on theoretical and applied issues.

V. Comparison of the Traditional and Inventive Problem Solving Approaches with TRIZ

The most important shortcoming of traditional methods is the loss of their usability when complexity of the problem increases. In Trial-error method, as the difficulty of the problem increases so does the number of attempts and thus time consumption and cost augments. Altshuller's study focuses on facilitation of the solution of hard creative problems and transfer of it to other people, this effort has led to the creation of TRIZ [6].

As TRIZ is offering a smart and cost-effective way to finding solutions to problems more quickly compared to the traditional problem-solving techniques, it helps engineers and scientists. TRIZ enables researchers to understand the actual functionality of problem solving, which results in designinig many traditional patents. TRIZ not only brings conceptual solutions to the problems but also becomes remedy to the problems of implementing these solutions.

From the point of comparative perspective it is also possible to assess TRIZ with other inventive methods. Evaluated together with other creative problem solving techniques such as Quality Function Deployment Design of Experiment, TRIZ is seen to have an important feature to fill the gaps that aren't addressed by these techniques. For the brainstorming groups, while providing an incentive to problem-solving process, it also focuses on helping their creativity. Together with the use of S-curve analysis and technological forecasting, TRIZ helps the ones who prepare product development strategies to make prediction about direction of the evolution of technology and product life cycle related to it [18]. Figure 6 includes a diagram illustrating the comparison of various inventive problem solving techniques with TRIZ. According to Figure 6, while TRIZ together with brainstorming appears to be the most successful method in production of new ideas, it stays away from industrialization, stands out as the most successful method with regard to efficiency.

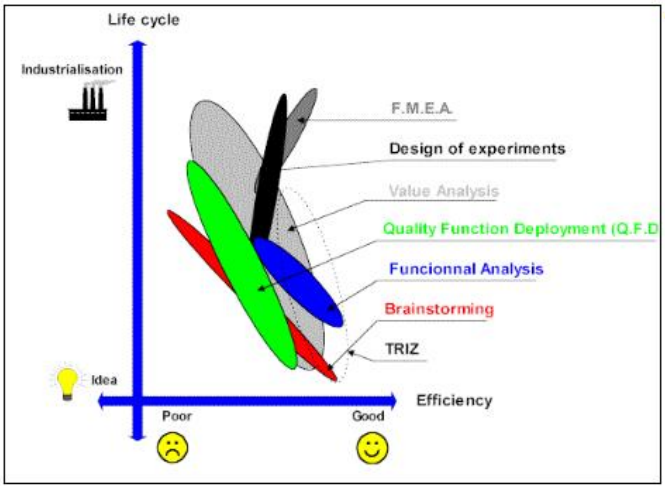

Fig 6. Comparison of various inventive problem solving techniques with TRIZ

5.1. Cooperation of the other inventive problem solving methods with TRIZ

5.1.1. TRIZ and Six Sigma

Six Sigma is a very structured quality improvement methodology and TRIZ is an inventive one; by applying both of them together, inventive problem solving tools can be used for quality improvement and the highest degree of quality can be achieved with inventive quality improvement methodology. [21]. As it is known, improving the quality of the product or service by reducing the number of errors made in production or service in an effort to increase customer satisfaction and profitability takes part in the development of the Six Sigma method.

At this point, the customer's demands, especially in a highly competitive environment, are very important variable which has become a target to be defined, predicted and, if possible,

affected. However, to do this, using the trial and error method is both time-consuming and risky. According to Averboukh, instead of using this, employing TRIZ's inventive approach will make a significant contribution to the Six Sigma solutions [22].

Using TRIZ's advanced methods and tools for the points where Six Sigma is insufficient in an effort to improve this method provides customer satisfaction and profitability growth by eliminating decision-making errors in definition, producing low-cost solutions in design, triggering the loss of time in analysis and measurement to reduce errors

5.2. TRIZ, Quality Function Deployment (QFD) and Taguchi Method

Quality Function Deployment (QFD) concentrates on "what the customer wants?" Thus, it really defines the "Functional Requirements" without actually concerning directly with the question: "how these functions are met and which technology is used?" The "house of quality" matrix qualitatively shows the gaps between organization's capabilities and customer requirements. QFD's "house of quality" can be used to point out conflicts and the parameters that conflict. This can be directly used by TRIZ's Contradiction Matrix to eliminate the conflict.

A Taguchi method reveals the need to determine the optimal parameters of processes and products for the best result. From time to time that the two process variables may create technical contradiction on the two or more features or a single variable producing good and bad features at different levels lead to physical conflict may be the case. The Taguchi method thus points out clearly the technical and physical contradictions and thus helps TRIZ in the sense of identification of the problem becomes easy TRIZ tools can then be applied to resolve the contradictions. Exactly in the opposite way, the innovative solution concepts of TRIZ can be verified, evaluated, implemented by planning an experiment where parameter settings can be optimized and best process can be selected [5]. Benefits using of QFD and TRIZ used together are shown in TABLE II [10].

5.3. TRIZ and Quality

Maintaining Quality management which leads to the emergence of contradictions in the life cycle of product or service necessitates the development of control systems in a continuous and creative manner. The growth of creativity helps the development of the concepts of product/process development and quality improvement. As analyses which are conducted for the quality is providing information about the customer requests and what the process with how many employees should be conducted, creativity is necessary to find ways of new products, services, processes and systems. [17].

In addition, when effects of ideality-oriented the point of view of a customer who is waiting for the products and services to be at the lowest cost with the highest functions, TRIZ's direct relation with the quality highlighting the creativity and creative problem solving occurs. The creativity is not enough on its own in order to achieve high quality. Customer-focused strategies, combined with creativity, give rise to high-quality products and services [88].

TABLE II
BENEFITS OF USING QFD AND TRIZ TOGETHER [10]

Development Phase	**QFD**	**Benefits of Using QFD and TRIZ Together**
Market Research	7 Product Planning Tools	Use Directed Product Evolution (DPE) with concept methods to show customers what new products will be like.
R&D	Technology Deployment	To solve engineering bottlenecks and contradictions
	Quality Deployment	To eliminate contradictions discovered by the roof of the House of Quality.
Design	Function Deployment	Use Strategic Unit-Field Analysis and DPE to identify new functions to excite customers.
	Reliability Deployment	Use Anticipatory Failure Determination to identify and prevent catastrophic failure modes in new products
	Concept Deployment	To develop new concepts by DPE patterns
	Cost Deployment	Use TRIZ to lower costs without resorting to tradeoffs.
Manufacturing	Equipment Deployment	Remove design constraints due to limitations of equipment and manufacturability.
	Process Deployment	Remove design constraints due to limitations of processes and people.
After Service	Service Deployment	Help in design for serviceability. Remove service bottlenecks

VI. CONCLUSION

TRIZ has defined evolution trends which are not bound to fields by exploring the systematic nature of technological evolution. A new classification has been created for design solutions. Contradictions are mentioned at the basis of the problems and inventions have been realized by destroying these contradictions. Some basic principles have been proposed for the elimination of contradictions and provided systematic access to these principles. Common patterns can be used in order to convert physical structures of the products by establishing models which is formed by interaction of material, space of systems or designs. TRIZ has also revealed some operations to overcome the psychological inertia of the designer or inventor. Several case studies have revealed that TRIZ has played a successful and accelerating role by enabling the invention of new conceptual solutions.

The path of rapid access to the necessary information which is the most important element of a successful creative design process is offered to with the help of TRIZ's extensive database. TRIZ provides in the form of systematic rules and guidelines that creative people can examine the past experience of creativity by taking advantage of knowledge of all the world's patents. Pointing to natural events and the physical effects, TRIZ organizes research which could fulfill

the function that is thought to be necessary for a system using a physical principle.

TRIZ not only presents an effective method in an effort for solving the problem for the users by defining an independent progress in the field of evolution patterns of the available systems, but also help making the prediction about future changes which can be made on the product or the features a new product needs to have. The purpose of TRIZ is not to supersede human creativity, but to enable the user to access necessary the information quickly by orginizing creative thinking process. To solve the recently-faced inventive problems users, without requirements of creative abilities they are adopted before, can perform the process by using TRIZ tools.

Recognized relatively late by the world owing to its date of emergence, but showing rapid development and deployment, theory of inventive problem-solving, TRIZ is a comprehensive, systematic and scientific problem solving and creativity method the frequent use of which is highly probable in the future. Furthermore, the businesses using different types of methods, with the development of theoretical infrastructure, seem likely to use their current practice method in a unified way with TRIZ. Businesses primarily, if needed, getting help from the current TRIZ consulting companies in an effort to train the expert staff who will use this method. TRIZ staff's examining TRIZ applications and getting used to the methods by making trials with TRIZ-based software and afterwards working to spread the method to the wider base are the levels which need to be taken into account within the scope of the transition to TRIZ. Increment of the number and the capabilities of softwares, making the educational process more clear and concise and in the event of enabling the provision of the introduction of TRIZ more common for the businesses who need to make improvements; this able method wil be able to serve to humanity in a broader way.

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REFERENCES

[1] H. Çağlar, "İnovasyon Yaratıcılığa Karşı", Inotec Bilgi Merkezi, 28, 2004.
Available: http://www.inotecbilgimerkezi.com/cinfocenter/Articles/art010604.asp

[2] Innovation,
Available: http://encyclopedia.learnthis.info/i/in/innovation.html

[3] Apte, P.R., Introduction to TRIZ Innovative Problem Solving
Available: http://www.ee.iitb.ac.in/~apte/CV_PRA_TRIZ_INTRO.htm

[4] G. Mazur, "Theory of Inventive Problem Solving (TRIZ)", 1995.
Available: http://www.mazur.net/triz/

[5] TRIZ Foundations
Available:http://www.ideationtriz.com/TRIZ_foundations.asp

[6] TRIZ
Available: http://www.mv.com/ipusers/rm/TRIZ.htm

[7] P. Manor, "The Principles of Inventive Thinking - Introduction to the Course of "Development of Inventive Thinking" According to the SIT", 2000.
Available: http://www.osakagu.ac.jp/php/nakagawa/TRIZ/eTRIZ/epapers/e2002Papers/eManor020721.html

[8] E. Yıldız, "Yaratıcı Problem Çözme Teorisi ve Uygulamaları, Graduation Thesis, Istanbul Technical University, Institute of Science, 2004.

[9] S. Pala, "TRIZ: A New Framework For Innovation - Concepts and Cases Overview, ICFAI University Press, 2005.
Available: http://www.icfaipress.org/books/TRIZ-C&C_ov.asp

[10] K. Yang and H. Zhang, "A Comparison of TRIZ and Axiomatic Design", TRIZ Journal, August 2000
Available: http://www.triz-journal.com/archives/2000/08/d/

[11] V. Souchkov, "TRIZ: A Systematic Approach to Innovative Design", 1996.
Available: http://www.insytec.com/TRIZApproach.htm

[12] T. Nakagawa, "TRIZ: Theory of Inventive Problem Solving – Understanding and Introducing It", 1998.
Available: hhttp://osaka-gu.ac.jp/nakagawa/TRIZ/eTRIZ/eIntroduction980517.html

[13] E. Domb, "Managing Creativity for Project Success", 7th Project Leadership Conference, June 2000.
Available: http://www.triz-journal.com/whatistriz/

[14] T. Nakagawa, "Let's Learn 'TRIZ'! A Methodology for Creative Problem Solving", 1999.
Available:http://www.osakagu.ac.jp/php/nakagawa/TRIZ/eTRIZ/epapers/eIntro990929/eIntro990929.html

[15] E. Domb, "The 39 Features of Altshuller's Contradiction Matrix", TRIZ Journal, November 1998 .
Available: http://www.triz-journal.com/archives/1998/11/d/index.htm

[16] TRIZ
Available: http://www.oxfordcreativity.co.uk/

[17] K. Tate and E. Domb, "40 Inventive Principles with Examples" TRIZ Journal, July 1997.
Available: http://www.triz-journal.com/archives/1997/07/b/index.html

[18] G. Altshuller, "The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity", Technical Innovation Center, Inc., Worcester, 2000.

[19] J. Marconi, "ARIZ : The Algorithm for Inventive Problem Solving An Americanized Leaning Framework", TRIZ Journal, April 1998.
Available: http://www.triz-journal.com/archives/1998/04/d/

[20] Averboukh, E., Six Sigma Trends: Six Sigma Leadership and Innovation Using TRIZ
Available: http://www.isixsigma.com/library/content/c030908a.asp

[21] A. H. M. Kermani, "Empowering Six Sigma Methodology via the Theory of Inventive Problem Solving (TRIZ)", TRIZ Journal, December 2003.
Available: http://www.triz-journal.com/archives/2003/12/h/08.pdf

[22] A. Zusman and B. Zlotin B, "Overview of Creative Methods", TRIZ Journal, July 1999.
Available: http://www.triz-journal.com/archives/1999/07/e/index.htm

[23] E. Domb, "TRIZ: The Science of Systematic Innovation", Portland International Conference on the Management of Technology, Portland. August 1999.
Available: http://www.thinksmart.com/2/conv2000/dombarticle.html

[24] K. Rantanen, "Brain, Computer and the Ideal Final Result", TRIZ Journal, November 1997.
Available: http://www.triz-journal.com/archives/1997/11/a/

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Real Time Virtual Mirror Using Kinect

G. Yolcu, S. Kazan and C. Oz

***Abstract*— This paper proposes a real time image processing approach to enable users to try virtual garments on in front of a virtual mirror. The user's hand motions select the clothes from a list on screen. Afterwards a virtual representation of the user wearing the selected virtual clothes appears in the virtual mirror. To create a more realistic effect, the system takes into account different images of the clothes according to different human poses and movements. Additionally, we developed an algorithm for matching up all motions between the virtual clothes and the human being. In this study, we benefit from the Microsoft Kinect SDK in order to follow the user's movements, coordinate the suitable clothe try-ons and provide depth sort effect to the human body and the clothes.**

Index Terms— **Virtual mirror, Virtual try-on, Virtual reality, Image processing, real time Systems, Kinect for Windows**

I. INTRODUCTION

PREVIOUSLY, people used to spend a lot of time while shopping. Owing to technological advances, online shopping has become very popular recently. Virtual mirror projects provide support for online shopping by offering the facility of selected clothes try-on. Therefore, users can see how they look in the clothes without physically putting them on, and without spending a lot time. Different virtual mirror projects have been in progress lately. For example, Cassas et al. developed a system that aims to facilitate the acquisition of certain skills by children. The augmented reality-system is designed as a mirror-world where users see themselves with virtual objects [1]. Murata et al. focuses on the "video mirror interface". A user can operate a computer system by selecting virtual objects on a screen with his/her hand [2]. Zhou et al. proposes a real time approach for virtual clothes fitting using Kinect [3]. Givonni et al. presents a virtual try-on system, which allows performance comparisons of their system with two skeletal tracking SDKs: OpenNI and Kinect for Windows SDK [4]. Hauswiesner et al. presents a system which combines image-based renderings of the user and previously uploaded garments. It transfers the garment recorded from one user to another by matching input and recorded frames [5].

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Besides clothing try-ons, virtual mirror projects are also used for glasses, jewelries, handbags, etc. For example, Wang et al. developed an augmented reality system for online shopping in which users can experiment with virtual handbags in different ways, such as sliding the handbag's straps to different positions on their arms and rotating the handbag [6]. Cho et al. developed a system in which the user is able to try on glasses [7].

Sometimes virtual mirror is designed for education. For example, Blum et al. presents an augmented reality magic mirror used for teaching anatomy by creating the virtual illusion that the user can look inside his body. They also used Microsoft Kinect [8].

The virtual mirror project presented in this paper has been developed mainly to help online shopping. In this work, we used the Microsoft Kinect for Windows sensor and the Kinect SDK. From the Kinect's skeleton library, we selected a human skeleton, on which we attempt to match the clothing items to the appropriate parts. Thanks to the skeleton library as well, when the user moves freely in front of the mirror, the clothes follow accordingly to such movements.

II. SYSTEM DESPCRITION

A. Adding virtual clothes on the video

In this work, a user stands in front of the monitor that is used as virtual mirror. Firstly, the user selects a clothing item from the list of clothes, which appears on the right side of the monitor, using his/her right hand. With the assistance of Kinect, the system follows and synchronizes the positioning of the right hand with a garment picture; the clothing item related to the garment picture the right hand is on, is placed on the user's body (Fig. 1).

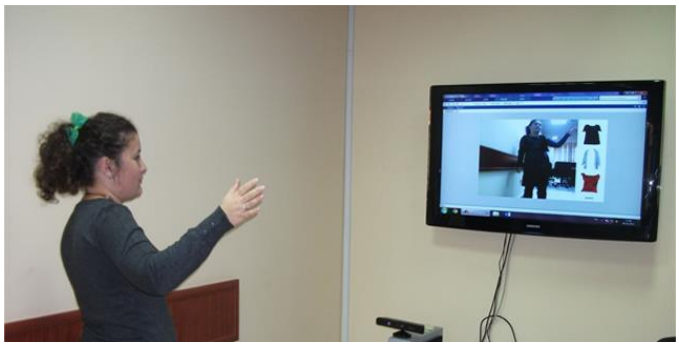


Fig. 1. Virtual mirror system

Secondly, the system focuses on correctly placing the garment on the skeleton. Again, Kinect ensures optimal results. Kinect also enables the access to the color image data

and depth image data, as well as audio data, streamed out respectively by the color and depth streams and the audio stream. In addition to the hardware capabilities, the Kinect software runtime implements a software pipeline that recognizes and tracks the human body. The runtime converts depth information into the skeleton joints of the human body making it possible to track up to two people in front of the camera [9]. The skeleton data consist of a set of joints. These joints are shown in the diagram below (Fig. 2).

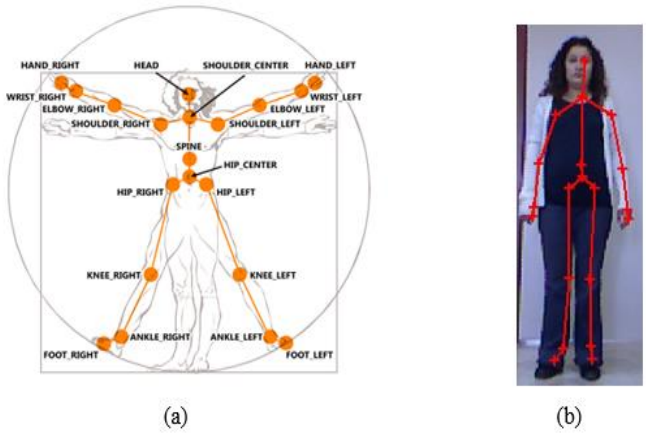


Fig. 2. (a)The skeleton joints which found by Microsoft Kinect (http://msdn.microsoft.com/en-us/library/hh438998.aspx) (b) Skeleton on a user

To place a virtual clothing item on the user, first we resize the image of the virtual garment based on the distance between the x-axis of the shoulders and between the y-axis of the hip center and shoulder center.

X-axis of virtual garment's' image=x-axis of shoulder left - x-axis of shoulder right

Y-axis of virtual garment's image=y-axis of hip center - y-axis of shoulder center

Owing to this step, clothe-sizing dynamism is capacitated to those who wear virtual clothes.

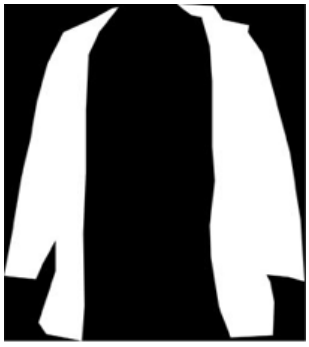


Fig. 3. Alpha Channel of a jacket

In the next step, the system positions the upper part of the garment based on the shoulder-center. To add the virtual clothes' image to the main video we use alpha channels of the images. As shown in Fig. 3, the alpha channel ensures that the background is black, with pixel value of zero, and the virtual garment area is white, with pixel value of 255. The main image is multiplied with virtual clothe image's alpha channel then the product is collected with virtual clothe image. So the clothing item's image is added to the main video without its background.

B. Virtual clothes transfer

Enabled by Microsoft Kinect skeleton map, the system follows the user's motions. Upon his/her body movements, the skeleton's related joints change, resulting in the change of position of the related clothing pieces.

To provide this modification capacity, ready images were produced and uploaded as follows: Firstly, a model performed possible movements in front of the screen. For every clothing item pose, the left arm angle for that movement from the waist up, or the y-axis coordinated distance between right and left feet for the that movement from the waist down were calculated and recorded. Secondly, the garment image was cut using Adobe Photoshop. Finally, it was added to the ready images database and the related calculation record.

The virtual mirror system follows the skeleton movement using Kinect, and as shown in TABLE I, calculates the arm angle for movements from the waist up and the y-axis coordinated distance between the two feet for the movements from the waist down. Next, it shows the suitable image available from the database. TABLE II shows in the first column real images of users moving freely, and in the second column, images of the users with the virtual clothes provided by the system on.

TABLE I
CALCULATING ARM ANGLE

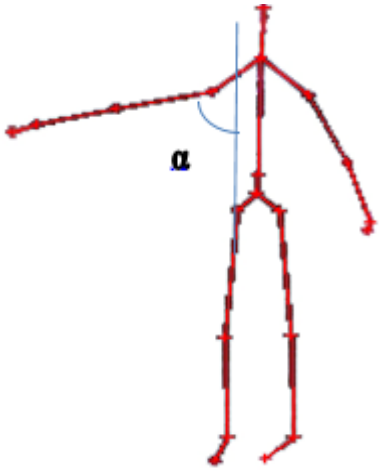
Formula	Figure
y = y-axis coordinate of wrist left - y-axis coordinate of shoulder left x = x-axis coordinate of shoulder left - x-axis coordinate of wrist left α = arctan (x / y)	

TABLE II
FREE MOVEMENTS IN FRONT OF THE MIRROR

Original frame	Virtual mirror frame
	

C. *Changing Color of Virtual Garments*

In our application, after being placed on the user's clothes, it is given the opportunity to the user to change the color of garment. To change color, user's left hand is followed by Kinect. When the left hand is on a color from the color list, color changing process takes place. While making color changes, it is required not to lose wrinkles and shadows on the garments. Because the wrinkles and shadows on the garments give a realistic impression. In HSV color space, if V parameters are held constant, the wrinkles and shadows can be kept constant. For this reason, color changing is provided in HSV color space. The color space of garment photo is translated from RGB to HSV. In HSV color space, H value which is expressing hue and V value which is expressing brightness are changed according to the selected color. After the changes, the photo is translated to RGB format.

Fig. 4. Different Colors sample of a garment

III. CONCLUSION

We worked on a real time image processing approach for a virtual mirror system. Firstly, we created a virtual clothes database indexed by skeleton posing. At run time, a user selects clothing items from a clothes list and moves freely. The system searches the database for suitable images and shows them on the user. We run our algorithm on a PC with a 2.80 GHz CPU and 3 GB RAM with no system delay.

The system works accurately, including the user fitting garment-resizing feature. Sometimes it works intermittently; to avoid this, more posed-clothing images can be uploaded to the database. In addition, the system uses Kinect; therefore, in order to use this system the user must have Kinect. As a means to increase the program functionality, making it more useful to a greater number of users, using a standard camera to record skeleton joint images is being considered, in place of Kinect. In this project, we analyzed arms and legs movements in this. Our future project improvement involves adding back and side turns, among other movement options.

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REFERENCES

[1] X. Casas, G. Herrara, I.Coma,M.Fernandez, "A Kinect-based Augmented Reality system for individuals with autism spectrum disorders ," international Conference on Computer Graphics Theory and Applications, Rome, 2012, pp.440-446

[2] K. Murata, M. Hattori, Y. Shibuya, "Effect of unresponsive time for user's touch action of selecting an icon on the video mirror interface," HCI International 2013, vol. 8007, pp. 462-468, July, 2013

[3] Z. Zhou, B. Shu, S. Zhuo, X .Deng, P. Tan, D. Lin "Image-based clothes animation for virtual fitting," SIGGRAPH Asia 2012 Technical Briefs,2012,doi: 10.1145/2407746.2407779

[4] S. Giovanni, Y.C. Choi, J. Huang, E.T. Khoo, K. Yin, "Virtual try-on using kinect and HD camera , " MIG 2012,vol. 7660, pp. 55-65, November, 2012
[5] S. Hauswiesner, M. Straka, G .Reitmayr, "Virtual Try-On through Image-Based Rendering," IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, vol. 19, no. 9, pp. 1552-1565,Sept.,2013.
[6] L. Wang, R.Villamil, S. Samarasekera and R. Kumar, "Magic mirror: A virtual handbag shopping system," 2012 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops, 2012© IEEE.doi: 10.1109/CVPRW.2012.6239181
[7] H. Cho, N. Schwarz "I like those glasses on you, but not in the mirror:Fluency, preference, and virtual ," Journal of Consumer Psychology 20, pp. 471-475, August, 2010
[8] T. Blum, V. Kleeberger, C. Bichlmeier, N. Navab, "Mirracle: An augmented reality magic mirror system for anatomy education," 19th IEEE Virtual Reality Conference, VR 2012, 2012©IEEE, doi: 10.1109/VR.2012.61 80909
[9] Microsoft, "Natural User Interface for Kinect for Windows," Available: http://msdn.microsoft.com/en-us/library/hh855352.aspx

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The Effects of Cure Conditions on Mechanical Properties of Polymer Modified Cement Mortars

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***Abstract*-The uses of polymers for various structural applications are gaining popularity throughout the World. In this study, three different types of polymers are added to cement mortars, and then these mortars are cured under three different cure conditions. Thus, it is aimed to investigate their mechanical contributions to mortars and to determine the most suitable cure condition for polymer modified concrete, comparatively. SBR, PSBR, MAD polymers are chosen as polymers. These polymers are added into the mortars in five different ratios (0.0%, 5%, 10%, 15%, 20%) by volume and the mortars are cured under three different conditions that watering twice a day (FCC), 16 hours in the water - 8 hours out (SCC), one day in the water - one day out (TCC). The mortars modified with MAD polymer show the best performance for chosen polymer addition ratios and also FCC is the most suitable cure condition.**

Index Terms—**SBR, PMC, compressive strength, flexural strength, deflection.**

I. INTRODUCTION

CONCRETE is a material that is strong against compressive loads, however, weak under flexural and tensile loads. Because of these weak properties, cracks seen at concrete elements are usual. One another phenomenon causing cracking for concrete is shrinkage.[1,2] A polymer is a large molecule composed of many repeated subunits, known as monomers. Polymers without chemical activity have compressive and tensile strengths higher than normal concrete. However, the elasticity modulus is lower and creep deformation is higher. Therefore, tensile streght of concrete is weak and that can improve with use polymeric material. For this objective, polymer concrete is identified in three groups [3- 6].

- Polymer Concrete: Only polymer is used as a binder.
- Polymer Modified Concrete: A polymer emulsion is used instead of a part of the mix water.
- Polymer Impregnated Concrete: A polymer is impregnated to cavities of hardened concrete.

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While polymer concrete and polymer modified concrete was known in the 1950s, polymer impregnated concrete has been used in the 1970s. Therefore, use of polymers in concrete has gained widespread. [7,8]. While very high compressive strengths concrete (140 MPa) is gained only in a few hours in polymer concrete, polymer modified concretes are known with provide excellent adhesion properties to the old. Polymer impregnated concrete generates high-strength concrete with superior impermeability[3]. Polymer impregnated concrete and polymer concrete is used less due to high material costs and technological challenges, but polymer-modified concrete is used commonly. Compared to normal concrete, polymer modified concrete is 2-3 times more costly, polymer impregnated concrete is 3-6 times more costly and polymer concrete is 8-20 times more costly [9].

Polymer-modified cementitious mixtures (PMC) have been called by various names, such as polymer portland cement concrete (PPCC) and latex-modified concrete (LMC). PMC is defined as hydraulic cement combined at the time of mixing with organic polymers that are dispersed or redispersed in water, with or without aggregates.

The majority of PMC placed today uses a polymer in latex form. Latex has been defined as a dispersion of organic polymer particles in water [10]. The average particle size varies from 100 to 2000 nanometers. Most latexes are made by a process known as emulsion polymerization, where the polymer is formed directly in water.[11]

A wide variety of polymer types have been investigated for use in PMC [12], but the major types in use today are as follows:

- Styrene-butadiene copolymers (S-B).
- Acrylic ester homopolymers (PAE) and copolymers,
- Particularly with styrene (S-A).
- Vinyl acetate copolymers (VAC).
- Vinyl acetate homopolymers (PVAC).
-

Selection of the type of polymer depends on the service life requirements and cost. It should be noted that PVACs should not be used where the PMC will be exposed to moist conditions.[13]

The main objective of this study is investigation of the effects of different types of polymers on mechanical properties of cement mortars. For this purpose thirteen different types of cement mortars are produced with three types of polymers and five types of addition ratios. Stiren Butadien Rubber (SBR), Polycarboxylate modified Stiren

Butadien Rubber (PSBR), Modified Acrylic Dispersion (MAD) polymers are chosen as polymers and these are added to mortars five different ratio (0%, 5%, 10%, 15% and 20%) by volume and the polymer modified mortars are cured under three different conditions watering twice a day(First Cure Condition (FCC)),16 hours in the water - 8 hours out(Second Cure Condition (SCC)) and one day in the water - one day out(Third Cure Condition (TCC)) The physical properties and flexural strengths, deflections and compressive strengths of the cement mortars are investigated.

It is worked with cement mortar instead of concrete. Since cement mortars more homogeneous than concrete, determining differences of polymers from each other will become easier. In other words, polymers effects on mortar are brought up clearly.

The essential cases separating this study from the others are;

- Uncommon polymers like PSBR and MAD are also used in this study.
- The tests are realized under three conditions FCC, SCC and TCC. Thus, the performance of polymers in wet and dry conditions will be introduced separately.

II. MATERIALS AND METHODS

A. Material

Three different types of polymer are used in the experimental process. These are SBR, MAD and PSBR polymers. Some properties of these fibers presented in (Table 1).

TABLE I
THE PROPERTIES OF THE POLYMER USED IN THE EXPERIMENTS

Material	SBR	MAD	PSBR
Specific Mass (kg/l)	1,005-1,025	1,08	1,01-1,04
pH Value	8-12	7-10	6
Colour	White	White	Light Bluish
Alkali Resistance	High	High	High

It is seen from Table 1, specific mass of the polymers are changed between 1.01-1,08 g/cm^3,pH values are changed between 6-12. The strongest properties of SBR are high alkali resistance.

In the experiments, CEM I 42.5 R type cement is used. The compositions, physical and mechanical properties of the cement are given in (Table 2). The experiments are conducted according to EN 196, so CEN-standard sand is used as aggregate in mortars.

B. Methods

In accordance with the objective of the study, thirteen different polymer modified cement mortars are prepared with three different polymer types and five different proportions (Table 2).

The flexural and compression tests were conducted according to the suggested principles in EN 196. The "test mortar" consists of 450 g of the cement mixture, 1350 g of graded standard sand, and 225 g of water, and consequently the water/cement ratio is 0.50.

TABLE II
MIX DESIGN OF THIRTEEN DIFFERENT FIBER REINFORCED MORTARS

Fiber ratio by volume	Cement (g)	Sand (g)	SBR, PSBR and MAD (g)	Water (g)	W/C
0%	450	1350	0	225	0,5
5%	450	1350	22,5	213,75	0,475
10%	450	1350	45	202,5	0,45
15%	450	1350	67,5	191,25	0,425
20%	450	1350	90	180	0,4

While polymer modified mortar is being produced, water is reduced by half the amount of polymer. After the mixing water is added to the cement-sand mixture, the selected polymer is added to fresh mortar and the mortar is mixed as long as obtained homogeneous mixture. After the molding process, the molds (with the mortars in them) were placed in the moist room at 23±1°C for 24 h and removed at the end of this period, and the mortar prismatic specimens were cured under three different conditions until 28 days. These conditions are watering twice a day (First Cure Condition (FCC)), 16 hours in the water - 8 hours out (Second Cure Condition (SCC)), one day in the water - one day out (Third Cure Condition (TCC)),. The tests are realized on the specimens for every condition. Thus, it is investigated the best performance of polymers, ratios and cure conditions.

When the curing time is completed, flexural and compressive tests are realized. Six specimens were tested for each type of mixture at each testing age according to the Rilem-Cembureau method in EN 196. While the flexural strength are determining, deflections are measured. The deflection used in comparisons is maximum deformation of midpoint of beams at breaking instant.

III. RESULTS AND DISCUSSIONS

The mortars containing different type and different proportions of polymers are investigated according to mass properties, flexural strengths, deflections and compressive strength.

A. The Effects of Polymer Type and Content on Unit Mass of Mortars

When SBR polymer which specific mass (1.05 g/cm^3) is lower than mortar (2.1 g/cm^3) is added to mortar, it is expected that the mortar's unit mass is decreases. It is seen from (Figure 1) and (Table 3) that PP fiber addition decreases unit mass of mortar. It is seen that MAD and PSBR presents similar results to SBR with 5% ration. The unit mass of mortar decreases down to roughly 1.80 g/cm^3 with the addition of 5% by volume of SBR, PSBR and MAD. All ratios of SBR and MAD similar behavior is observed. But, for PSBR with 5%, 10%, 15%, 20% constant decrease is observed. The biggest decline is observed with 29% for PSBR with 20% ration.

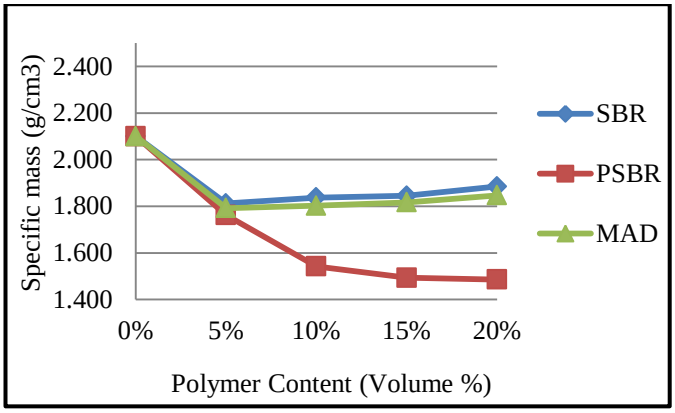

Fig. 1. *Relationship between polymer content and specific mass*

TABLE III
SPECIFIC MASS OF POLYMER MODIFIED MORTARS

	Dry Specific mass (g/cm3)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	2,100	2,100	2,100
5%	1,812	1,762	1,792
10%	1,837	1,542	1,802
15%	1,845	1,493	1,817
20%	1,885	1,486	1,847

B. The Effects of Polymer Type and Content on Flexural Strength of Mortars

Polymers are added into the mortars in five different ratios (0%, 5%, 10%, 15%, 20%) by volume and the polymer modified mortars are cured under three different conditions, watering twice a day (First Cure Condition (FCC)), , 16 hours in the water - 8 hours out(Second Cure Condition (SCC)) one day in the water - one day out(Third Cure Condition (TCC)). Flexural strengths of the cement mortars are investigated.

Flexural strengths of 0%ration specimens are investigated that average 6,42 N/mm^2 for FCC (Table 4). The results of experiments with %5, %10, 15% SBR addition, flexural strengths of mortars increase according to 0% addition. But, flexural strengths of mortars with SBR 20% decrease according to 0% addition. All ratios of PSBR and MAD similar behavior is observed. Both PSBR and MAD while the flexural strengths of mortars with 5% ratio decrease, with 10%, 15%, 20% ratios increase (Figure 2). MAD shows the highest strength with 20% ratio.

TABLE IV
FLEXURAL STRENGTH OF POLYMER REINFORCED MORTARS

	Flexural Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	6,42	6,42	6,42
5%	7,48	4,57	5,09
10%	6,96	6,09	7,03
15%	7,97	5,88	7,01
20%	5,86	8,51	9,05

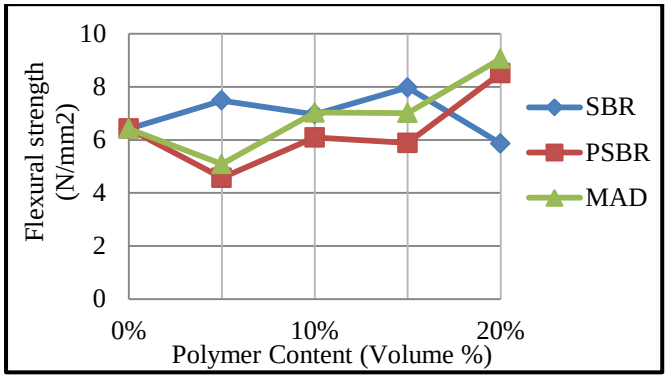

Fig. 2. *Relationship between polymer content and flexural strength in FCC*

Flexural strengths of 0%ration specimens are investigated that average 6,24 N/mm^2 for SCC. While the flexural strengths of mortars for SBR with 5% ratio increase, both MAD and PSBR decrease (Table 5). The flexural strengths of mortars for SBR with 10%, 15%, 20% ratios reduce, but for MAD with same ratios increase as well as PSBR cannot show fixed change (Figure 3). Flexural strengths of 0%ration specimens are investigated that average 6,24 N/mm^2 in TCC. The flexural strengths of mortars show similar behavior in SCC and TCC (Table 6 and Figure 4).

TABLE V
TABLE 5. FLEXURAL STRENGTH OF POLYMER MODIFIED MORTARS

	Flexural Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	6,24	6,24	6,24
5%	7,03	3,84	3,18
10%	5,95	5,71	3,65
15%	5,84	5,03	4,19
20%	5,74	5,66	6,15

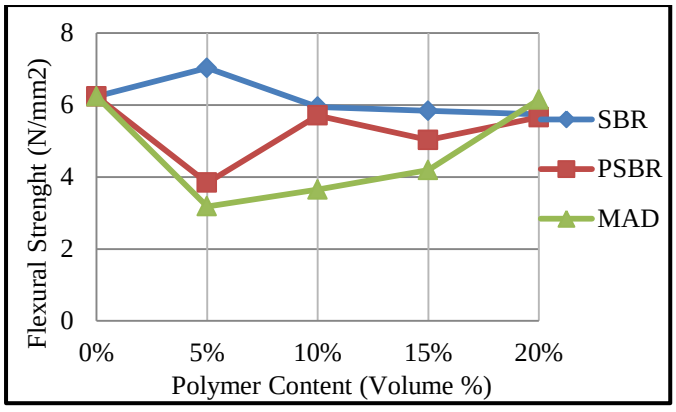

Fig. 3. Relationship between polymer content and flexural strength in SCC

TABLE VI
FLEXURAL STRENGTH OF POLYMER MODIFIED MORTARS

	Flexural Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	6,75	6,75	6,75
5%	6,73	5,15	4,57
10%	6,77	7,49	5,78
15%	5,77	3,79	5,87
20%	4,99	5,19	7,18

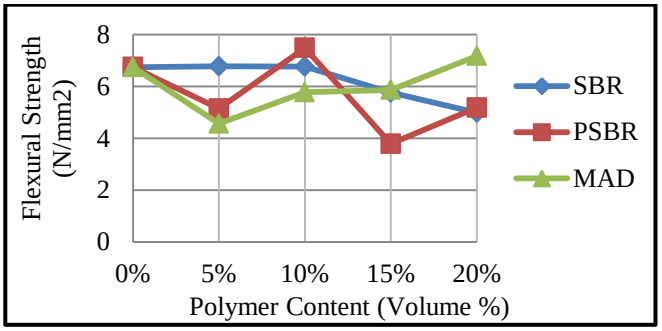

Fig. 4. *Relationship between polymer content and flexural strength in TCC*

FCC is the most suitable cure condition for flexural strength. PSBR and MAD provide increase (8,51 N/mm^2 – 9,05 N/mm^2) 24% and 29%, respectively. The biggest decline is observed with 49% for MAD in SCC.

C. The Effects of Polymer Type and Content on Deflections of Mortars

While flexural strengths are being tested, deflections of the beam samples are determined. One important reason of polymer addition to mortar is increasing ability of ductile behavior of mortars and so not to crack under small tensile stress. Thus, high level of deflection ability is desired.

TABLE VII
TABLE 7. DEFLECTION OF POLYMER MODIFIED MORTARS

	Deflection (mm)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	1,313	1,313	1,313
5%	1,207	0,780	1,291
10%	1,355	1,200	1,380
15%	1,531	1,232	1,536
20%	1,441	1,387	1,797

Both FCC and SCC especially the mortars contain SBR, PSBR and MAD present high level of deflection with 20% addition (Table 7, Figure 5). For the mortar has MAD, deflection increases as much as 36% in FCC. For PSBR mortar the deflections a bit less than the samples with reference specimen (0% ration) in SCC. The samples have SBR polymer is not influenced from increasing of polymer addition ratio, especially in SCC (Table 8, Figure 6). All polymer modified mortar present a diminish for all ratios in TCC. (Table 9, Figure 7). PSBR has the highest decrease 28% with 20% ration in TCC (from 1.782mm to 1.274mm). Direct relationship cannot setup between the deflections and flexural strength of mortars.

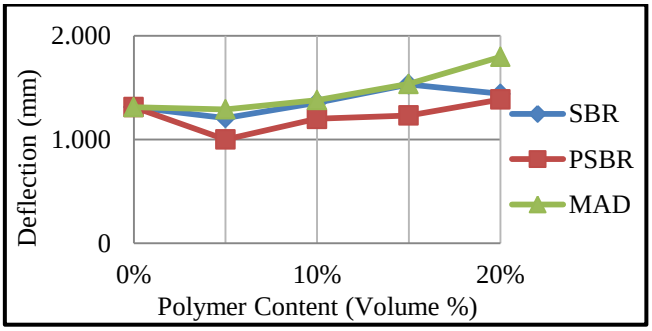

Fig. 5. Relationship between polymer content and deflection in FCC

TABLE VIII
DEFLECTION OF POLYMER MODIFIED MORTARS

	Deflection (mm)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	1,300	1,300	1,300
5%	1,336	1,197	0,857
10%	1,339	1,470	1,202
15%	1,302	1,280	1,306
20%	1,181	1,590	1,414

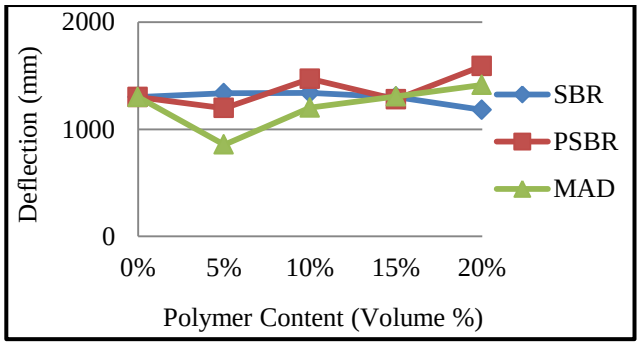

Fig. 6. Relationship between polymer content and deflection in SCC

As mentioned before, all mortars with 5% polymer addition present the worst character. MAD has the highest flexural strength, interestingly, does not show good performance in compressive strength in FCC, too.

TABLE IX
DEFLECTION OF POLYMER MODIFIED MORTARS

	Deflection (mm)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	1,782	1,782	1,782
5%	1,360	1,689	1,163
10%	1,419	1,722	1,215
15%	1,400	1,674	1,251
20%	1,296	1,274	1,495

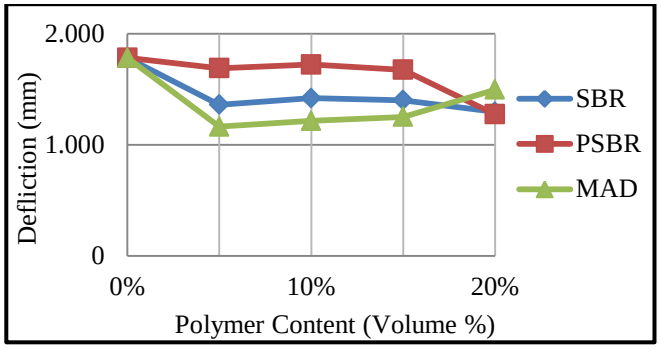

Fig.7. *Relationship between polymer content and deflection in TCC*

D. The Effects of Polymer Type and Content on Compressive Strength of Mortars

If the mortars have different polymer types are investigated, the compressive strength decreases with addition of all of the polymers types for both FCC and SCC. However, there is a bit increase in TCC for SBR with 10%, 15% and 20% rations.

TABLE X
Compressive Strength of polymer modified mortars

	Compressive Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	50,73	50,73	50,73
5%	38,91	29,79	19,85
10%	27,73	42,6	30,91
15%	32,31	42,68	24,89
20%	37,82	42,57	27,36

When SBR, PSBR and MAD are added with 5% ration, compressive strength of mortars dramatically decrease in FCC (Table 10, Figure 8). MAD has the highest diminish from 50.7 N/mm^2 to 27.36 N/mm^2 (60%) with 5% ration in FCC, according to 0% ration. If PSBR is added with 10%, 15%, and 20% ratios, compressive strength of mortars is not show a change almost in FCC.

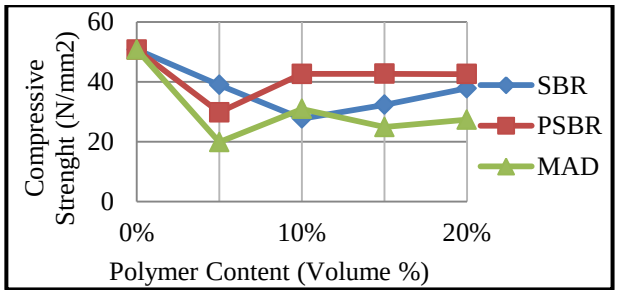

Fig. 8. Relationship between polymer content and compressive strength in FCC

For SCC with 5% polymer additions, a diminish is observed. These ratios changes as 33% for SBR, 23% for PSBR and 57% for MAD. Both PSBR and MAD show similar behavior for all ratios in SCC (Table 11, Figure 9).

TABLE XI
COMPRESSIVE STRENGTH OF POLYMER MODIFIED MORTARS

	Compressive Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	48,45	48,45	48,45
5%	38,61	26,01	27,1
10%	32,05	41,49	31,5
15%	29,51	40,78	29,1
20%	32,38	37,01	20,6

MAD has the highest diminish from 48.45 N/mm^2 to 20.6 N/mm^2 (57%) with 20% ration in SCC, according to 0% ration.

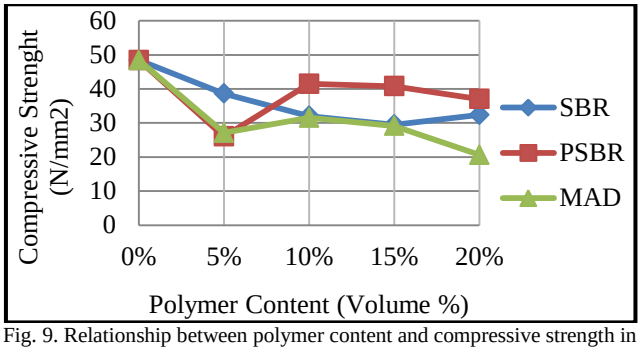

Fig. 9. Relationship between polymer content and compressive strength in SCC

When SBR, PSBR and MAD are added with 5% ration, compressive strength of mortars dramatically decreases in TCC (Table 12, Figure 10). MAD has the highest diminish from 51.21 N/mm^2 to 19.53 N/mm^2 (62%) with 20% ration in TCC, according to 0% ration. If PSBR is added with 10%, 15%, and 20% ratios, compressive strength of mortars show a bit increase, according to 0% ratio.

TABLE XII
COMPRESSIVE STRENGTH OF POLYMER MODIFIED MORTARS

	Compressive Strength (N/mm2)		
Fiber ratio by volume	SBR	PSBR	MAD
0%	51,21	51,21	51,21
5%	37,1	27,46	26,66
10%	50,76	36,82	35,09
15%	50,84	38,27	22,64
20%	51,88	36,87	19,53

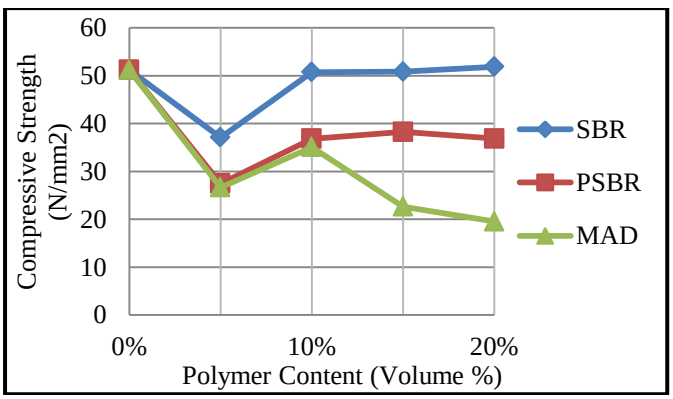

Fig.10. Relationship between polymer content and compressive strength in TCC

Although the polymers contribute flexural strength of mortar, they influence negatively on the compressive strength, when designing mix of concrete, strength class must selected one level high. For examples, if it will be produced C25/30 polymer concrete, at least C30/37 class concrete should be designed according to EN 206 concrete classes.

E. Determining Optimum Polymer Content from Relation between Flexural and Compressive Strength

As investigated above, with fiber addition, while flexural strength improves, compressive strengths influenced negatively. In this subsection, it is trying to be determined the optimum cure condition and the optimum polymer ratio that present better compressive strength and flexural strength for each polymer types separately. Since under SCC and TCC polymer modified mortars present unstable behavior, these comparisons are set up only for the samples under FCC.

It is understood from discussion above that each polymer show the best performance different addition ratio and different cure condition when flexural and compressive strength taken into consideration at the same time. It is seen that for after 5% addition ratio, flexural strength of PBSR and MAD increases and compressive strength remain reasonable level under FCC. However, big increase at 20% in flexural strength is taken into consideration; it can be said that these addition ratios are the best for MAD in FCC. For the samples have SBR show best results at 15% in FCC. The samples contain PSBR polymer give optimal results at 20% in FCC.

IV. CONCLUSIONS

It is investigated in this study that the effects of polymer types and content on mechanical and physical properties of cement mortars. The conclusions drawn from this study are;

i. Different types of polymers and cure conditions contribute to flexural strength at different contents. PSBR and MAD show best increments in flexural strength at 20% polymer content as 24% and 29%, respectively in FCC. For SBR, 24% increment in flexural strength is obtained at 15% polymer content by volume in FCC. Flexural strength of PSBR and MAD decrease at 5% ration for all cure condition.

ii. For all polymers types, addition of polymers decreases compressive strength. With 5% polymer addition for FCC, compressive strengths of mortars decrease 23% for SBR, 42% for PSBR, 60% for MAD. Only for SBR, in compressive strength of mortars is not observed a decrease at 10%, 15% and 20% ratios in TCC.

iii. Both FCC and SCC especially the mortars contain PSBR and MAD present high level of deflection in 20% ratio. The samples have SBR polymer are not influenced from increasing of polymer addition ratio in SCC. For all polymers show a decrease in TCC.

iv. The best of cure condition is investigated as FCC. Flexural strength and deflection show an increase in this condition. However, compressive strength shows a decrease for all ratios in FCC.

v. When polymer which specific masses are rather lower than mortar are added to mortar, the mortar's unit mass is decreases. SBR and PSBR show similar behavior in all ratios. It is seen that 20% SBR and MAD polymers addition decreases unit mass 10-15%, however PSBR decreases dramatically (29%).

vi. Since fiber addition influence negatively on the compressive strength, when designing mix of concrete, strength class should be selected one level high.

vii. All polymer increase consistency and workability of mortars especially at high dosages.

viii. Each fiber shows the best performance different addition ratio and cure condition when flexural and compressive strength taken into consideration at the same time. The optimum polymer addition ratios of the samples contain SBR are 20% for FCC. For the samples have PSBR show best results at 20% in FCC. The samples contain MAD polymers gives optimal results at 20% in FCC.

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REFERENCES

[1] Jackson N and R. Dhir, Civil Enginnering Materials, Palgrave Publishers Ltd, London, 1996.
[2] A. Çavdar, The Effects of Types and Content of Fibers on Mechanical Properties of Cementitious Composites, 2012
[3] Baradan, B., Yazıcı, H. ve Aydın, S., Beton, Dokuz Eylül Üniversitesi Mühendislik Fakültesi Yayınları, İzmir, 2012.
[4] Mehta, P.K. and Monterio, P.J.M., Concrete, Microstructure, Properties and Materials, McGraw Hill, 3rd Edition, 2006.
[5] Neville, A.M. and Brooks, J.J., Concrete Technology, 2nd Edition, Prentice Hall, 2010.
[6] T. Özturan, Özel Betonlar, Boğaziçi Üniversitesi, İstanbul, 2012
[7] Fowler, D.W., "Polymers in Concrete: A Vision for the 21st Century", Cement and Concrete Composites, V.21, pp. 449-452, 1999.
[8] Ohama, Y., "Recent Progress in Concrete – Polymer Composites", Advanced Cement Based Materials, V.5, pp. 31-40, 1997.
[9] Mindness, S. And Young, J.F., Concrete, Prentice Hall, New Jersey, 1981.
[10] Walters, D. G., "What are Latexes?" Concrete International, V. 9, No. 12, December, 1987, pp. 44-47.
[11] ACI 548. 3R-03, Polymer-Modified Concrete
[12] Ohama, Y., "Polymer-Modified Mortars & Concretes," Concrete Admixtures Handbook, Edited by Ramachandran, V. S., Noyes Publications, 1984, pp. 337-429.
[13] ACI 548. 1R-97, Guide for the Use of Polymers in Concrete.

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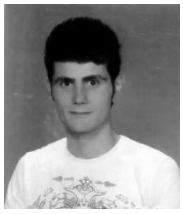

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Quality Function Deployment and Its Application on a Smartphone Design

B. Cerit, G. Küçükyazıcı, and G. Kalem

***Abstract*—The aim of this paper is exploring the application of the Quality Function Deployment (QFD) method on a new product development in accordance with customer expectations. The design of a new smart phone has been selected as the research case. QFD researches have been examined and literature scanning has been performed for the telecommunication industry. However, it was not easy to find so many QFD sample projects in the sector due to fact that product life cycle are completed very fast. It is required to grab competitive advantage by means of continuous review of new product development techniques because mobile communication technologies are so dynamic in many aspects. In addition, updated information and short history related to the telecommunication sector and mobile phone market including smart phones have been examined. It is aimed to understand QFD application well by explaining characteristics of smart phones and their development stages in the research.**

Index Terms—**Quality Function Deployment, Kano Model, Telecommunication, Smart phones**

I. Introduction

NOWADAYS, the ability to present new products to the market in a fast way while satisfying customer expectations is getting more importance for the entire customer focused firms. New quality techniques have started to appear in order to shorten the production loops, to enable the firms to respond to customer demands, and to gain advantage in the market. Quality Function Deployment (QFD) is one of these techniques, which has started and spread from the 'quality' concept so as for the firms to meet customer expectations. The majority of the firms are using QFD in today's business world, where fast responds to customer demands are gaining more importance every day.

QFD collects customer demands through various methods and converts them into technical necessities, which allows the resources to be allocated considering customer priorities. The focal point is the customers' requirements and expectations. Products are developed considering the determined targets and priorities. QFD is a method to guarantee the quality while the product is just beginning to be designed.

Mobile communication, where customer focus of QFD is the main subject, is one of the leading industries in Turkey. The industry players need a systematical approach in order to respond to customer requirements and expectations under fierce competition so as to continue being a player in this industry. QFD, which listens to the customers' voice and guarantees the quality of the product or the service, is a Quality Management Technique which can be applied in mobile communication industry's business conditions.

The aim of this study is to apply QFD methodology in order for Turkey's leading mobile communication operator to design a smart phone, which will be put on the market in the last quarter of the year 2013. In the first section, literature research is conducted in order to give brief information on QFD. In the second section, the case study of the operator is explained in detail. The operator has decided to name the smart phone project as "Gebze". Gebze Project was first presented as the local smart phone to the industry in the Mobile Worlds Congress, which was held in Barcelona on February. The QFD application also supports the Kano Model during the grouping and prioritization of the customer necessities, which enables more sensitive results. The findings are interpreted in the conclusion, taking customer expectations into account.

II. Literature Review

In smart phones market, it is very critical to apply quality techniques in a fast and correct way in order to meet the necessities of product/service market, since the demands are dynamic and unsteady. This will also assure the firms to consume their resources in the right way. Although QFD practices have been applied to the products and services of smart phones, any specific study regarding the design of the phones haven't been found during the literature survey. This shows the lack of QFD applications in this industry. More information regarding QFD-applied mobile communication industry is going to be given in detail in this section.

QFD methodology was applied in mobile service industry in a workstudy conducted in the University of Oulu in Finland in 2005. A general framework was proposed in order to improve mobile service design by using QFD concepts. QFD application was explained to the students and lecturers via an e-learning example, specially designed for that purpose. A

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brain storming session was conducted between the search engineers in order to determine the most important technical properties demanded by the customers, and 7 properties were defined. Data Transfer Rate was found to be the most critical necessity in e-learning services [1].

Although there are so many mobile device producers, only Nokia has conducted academically known QFD studies. One of the main reasons which caused the firms not to spend time applying QFD may be the short product life cycles in this industry. Another reason may be the disadvantage of a large-scale House of Quality, which cannot be avoided in order to collect the necessies under the same roof. This disadvantage may override the easy-application and fast-learning advantages of QFD [2].

Nokia decided to conduct a comprehensive QFD study in 1998 in order to develop product definition processes. The first step was to focus on the Japan market, with the mission of "using QFD in describing the future products". The research was completed by collecting the customer's voice. The advantages of this study wil be summarised as follows [2]:

- The benefits which are provided by the mobile phones have been understood so as to be optimized in the future products.
- Necessities and/or problems which may not have been recorded by traditional methods have been explored.
- The main innovation proceesses appreciated by the customers have been discovered and focused on.

Nokia benefited from the QFD methodology in another study conducted in the University of Lappeenrannan in Finland in 2000, aiming to improve the efficiency of product development processes of mobile phones. Conflicting product parameters were intended to be detected and cleared. It is very important to understand customer expectaions correctly and respond to them as quickly and as truly as possible in the fierce competition market of mobile phones where customer demands vary too fast. Nokia has constituted a constant product development process via these QFD studies [3].

The University of Abu Dhabi conducted a QFD project in Pakistan in 2011 to increase customer satisfaction of Ufone and Mobilink. The data was collected from customers, employees and the managers of the operators.QFD Matrix was used in order to detect the customer requirements and to analyze the comparison of pre-paid services. The results indicate that QFD enables a firm not only to gain a competitive position, but also to have competitive advantage. QFD can be much better than traditional management tools provided that the managers listen to the customers' voice and make demanded adaptations in the products and services. The traditional tools just take the managers' aspect into account, however QFD listens to the customers [4].

The Institute of Technology at Linköping University in Sweden used QFD methodology at Ericsson Mobile Phone Production Center to increase the quality of production in 2002. The aim was to form a flexible production line by QFD, since QFD would enable knowing much more detail about customer needs. The facility at Linköping was one of the seven production facilities of Ericsson Mobile Communication (EMC). The main subject was flexibility so Ericsson needed to take care of some points while positioning itself in the mobile phone market, which are constant and sharp demand increases, growing product portfolios and increasing demands for customisation, the consumer market created by increaing competition, and fast variations in the market.

The basis of the study was Ericsson's focus on innovation, rather than Nokia's focus on customers. Nokia was the first producer to introduce replacement parts for mobile phones to the customers. Ericsson also wanted to increase its customer focus and A1018s was the first step to serve this intention. House of Flexibility was created at this point via QFD in order to convert competitive priorities to production output flexibilities. The results indicates that QFD is an important methodology not only for quality management bu also for the ceration of a flexible system [5].

III. CASE STUDY

In 2010 the firm started to launch its own smart phones to the market while it had been going on marketing world renowned smart phones such as iPhone and Samsung Galaxy series in Turkey. T11, T20, T21 and T30 are the smart phone models launched with the operator's own brand in 2011 and 2012. The firm targeted on mid and low level customer segments between the age of 16-55 having a smart phone first time. The firm uses two equipment manufacturers (Huawei and ZTE) in production of these smart phones. These companies' headquarters are located in China, but have operations all over the world. The operator determines the smart phone designs in terms of software and hardware before the mass production. Customer requirements and demands are playing main role in this point. Prototype devices are subjected to some tests by technical units of the firm and analyzed in detail before their launch.

Privacy has high importance in the mobile communication sector because of fierce competence. Therefore, prototype devices are tested by the firm's technical and non-technical employees internally as well as they use these smart phones in their daily lives. Consequently, defects and development areas are informed to the device manufacturers and these feed-backs go on until the mass production phase. Technical teams (engineers) perform some functionality and network performance tests for the devices. On the other hand, non-technical employees (sales and marketing teams) use these phones with the end user perspective.

Customer questionnaire is arranged in order to collect the voice of customer (VoC). Target customers being included in the project are the employees from sales, marketing, vendor management, terminal test and network quality assurance departments. As explained above, these persons have usage experience of T21 and T30 respectively. Distribution of questionnaire papers was handled via e-mail because the most of employees works in different locations of the firm.

3.1 Application Steps of Quality Function Deployment

3.1.1 The determination of satisfaction criteria

Initially, focus group meetings were performed with the attendance of network quality assurance and terminal testing teams and then important characteristics of a smart phone were discussed amongst these technical groups. In addition, some other meetings were arranged with the team who is responsible for only T series smart phones and acquired their help. On the other hand, all the literature was surveyed deeply and conference papers and articles published in international area were taken into consideration while determining these customer satisfaction criteria, which are Ease of use, Switch speed between the interfaces, Visuality (interface), Internet connection rate, Variety of applications, Long battery life, Entertainment platform such as music, video and game, Functionality, Network performance (calling, being called, data transfer etc.), Messaging (SMS, MMS, e-mail and instant messaging), Mobile payment, Map, navigation and location based services, Social media applications, Screen size and Sensitivity of touch screen [6-7].

3.1.2 The determination of target customer features

In the foreground of these satisfaction criteria for smart phones, non-technical teams from sales, marketing and vendor management department attended in the customer questionnaire. The biggest factor affecting this choice of this questionnaire group is that these persons are positioned so close to the real customers of the firm. Additionaly, these employees use the smart phones in their daily life under test process and have opportunities of trying device features and observing its performance. Thus, it was considered that questionnaire results tend to be quite similar to the real customers' outputs due to their strong relationship and direct communication with subscribers of the firm.

3.1.3 The determination of customer requirements' importance levels

The aim of QFD application on T30 smart phone which is launched after T21 is to find in which level the existing phone satisfies the customer requirements and expectations and also to point out the improvement points of the smart phone. Therefore, in the A section of questionnaire it is wanted questionnaire group to give a score between 1 and 5 for each satisfaction criterion. Here the score "1" means the lowest importance and "5" means the highest importance. The level of importance is calculated from average of replies to the customer requirements.

3.1.4 The analysis of customer satisfaction levels

In the B section of questionnaire it is wanted the customers to evaluate the satisfaction levels of T21 and T30 smart phones for their expectations. Here the score "1" means that the customer criterion is not satisfied at all, "5" means that the customer criterion is satisfied completely. Then after that arithmetic average is calculated from all replies.

The data extracted in this section can be seen in Figure 1. Sales advantage values are determined by the sales employees. "Improvement Ratio", "Absolute Weight" and "Relative Weight(%)" are calculated after determination of quality level and sales advantage values targetted.

$$\text{Improvement Ratio} = \frac{\text{Intended Quality Level}}{\text{Satisfaction of QFD Firm}} \quad (1)$$

$$\text{Absolute Weight} = (\text{Importance Level}) \times (\text{Improvement Ratio}) \times (\text{Sales Advantage}) \quad (2)$$

$$\text{Relative Weight (\%)} = \frac{\text{Absolute weight of any row}}{\text{Total absolute weight}} \times 100 \quad (3)$$

The results obtained from these formulas can be seen in Figure 1.

	Importance Level	T30 Satisfaction	T21 Satisfaction	Intended Quality	Corrected Improvement Ratio	Sales Advantage	Absolute Weight	Relative Weight
Ease of use	4,1	2,6	2,5	4,1	1,58	1,5	9,7	11,54
Switch speed between the interfaces	4,3	3,1	1,7	4,3	1,39	1,5	8,95	10,65
Visuality (interface)	3,5	3,1	2,2	3,5	1,13	1,2	4,74	5,64
Internet connection rate	3,8	3,3	2,5	3,8	1,15	1,2	5,25	6,25
Variety of applications	3,3	3,1	3	3,3	1,06	1	3,51	4,18
Long battery life	4,1	2,2	2,4	4,1	1,86	1,5	11,46	13,64
Entertainment platform such as music, video and	2,8	3	2,9	2,8	0,93	1	2,61	3,11
Functionality	3,7	3,1	2,2	3,7	1,19	1,2	5,3	6,31
Network performance (calling, being called, data	3,9	3,2	2,8	3,9	1,22	1,2	5,7	6,79
Messaging (SMS, MMS, e-mail and instant	3,8	3,5	2,4	3,8	1,09	1,2	4,95	5,89
Mobile payment	2,1	3	2,7	2,1	0,7	1	1,47	1,75
Map, navigation and location based services	2,7	3,2	2,5	2,7	0,84	1	2,28	2,71
Social media applications	3,7	3,6	2,8	3,7	1,03	1,2	4,56	5,43
Screen size	3,6	3,8	2,6	3,6	0,95	1,2	4,09	4,87
Sensitivity of touch screen	4,2	2,8	1,8	4,2	1,5	1,5	9,45	11,25

Fig 1. The analysis matrix of customer satisfaction levels

3.1.5 The determination of technical features

The brain storm meetings executed amongst terminal testing and network quality assurance departments enabled the determination of technical requirements that will satisfy the customer demands. Additionally, smart phones' technical specifications acquired from literature survey were included in this list. Lastly, technical features that take place in literature were examined in detail when the focus group meetings were arranged and then reduced to the following list. Thus, construction of house of quality (HoQ) and interpretation become easier. Literature survey is a significant part of this study. Especially up-to-date articles published after 2009 are

taken into consideration. The reason is that technical specifications evolved profoundly while the market had been passing from classical mobile phones to the smart phones.
Basic technical features determined for the smart phones are listed below [6-7]:

1. Network technology supported by device
2. Operating system
3. Hardware (HW) design
4. Software (SW) design
5. Processor (CPU) power
6. Memory capacity
7. Connection capabilities such as Bluetooth, WiFi, NFC and A/GPS.

3.1.6 The development of the correlation matrix between customer and technical requirements

Another questionnaire is utilized in order to measure the correlation level between customer and technical requirements as well. This study makes clear in which level each technical specification meets customer requirements. Some technical features determined by expert engineers in their areas may not be so necessary or completely necessary. This grading comes up with the correlation of two categories. Correlation matrix is formed after getting item weights of questionnaire results for the relationship between customer demands and technical requirements. The correlation values obtained here can be seen in Figure 2.

3.1.7 The calculation of technical requirements' absolute and relative importance levels

Absolute and relative importance levels are calculated by using the connections between customer demands and technical requirements and then written as shown in Figure 2.

Technical Requirements / Custormer Requirements	Network technology supported by device	Operating system	Hardware (HW) design	Software (SW) design	Processor (CPU) power	Memory capacity	Connection capabilities such as Bluetooth, WiFi, NFC and A/GPS	ABSOLUTE WEIGHT
Ease of use		9	3	9	9	3	3	9,7
Switch speed between the interfaces		9		9	9			8,95
Visuality (interface)		9		9				4,74
Internet connection rate	9	3	9	3	3	1	3	5,25
Variety of applications		9		3		3		3,51
Long battery life	3	3	9	3	1			11,46
Entertainment platform such as music, video and		3		1	3	9		2,61
Functionality	3	9	3	9	3	1	9	5,3
Network performance (calling, being called, data	9	1	9		1			5,7
Messaging (SMS, MMS, e-mail and instant	3	1		1	1	1		4,95
Mobile payment		3	3	9			9	1,47
Map, navigation and location based services	3	9		9	3	1	9	2,28
Social media applications	3	3		3	1	1		4,56
Screen size			9		3			4,09
Sensitivity of touch screen		3	9	3	3			9,45
Absolute Importance	184,2	425,4	373	402,2	281,5	85,46	126,3	
Relative Importance (%)	9,81	22,65	19,86	21,42	14,99	4,55	6,73	

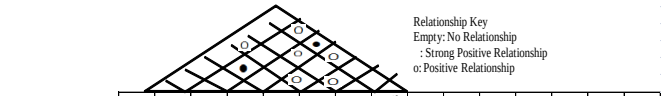
Fig 2. Absolute and relative importance levels

3.1.8 The determination of correlations amongst technical requirements

How technical features affect each other is handled in correlation matrix under the roof of house of quality. There are lots of weak or strong positive correlations between many technical specifications of smart phones. For instance, operating system plays significant role in software design of smart phone. At the present day, updated versions of operating systems seem quite user-friendly and bring lots of functions to the customer in a simple way. Besides there is a similar correlation between processor power and software design, but correlation level can be regarded as relatively weak because processor power does not affect directly.

3.1.9 The formation of House of Quality

At the last stage of the formation of house of quality, customer satisfaction values of T21 smart phone, previous model than T30, are extracted from questionnaire results and located on the House of Quality. It is shown in Figure 3.



Technical Requirements / Custormer Requirements	Importance Level	Network technology supported by devicei	Operating system	Hardware (HW) design	Software (SW) design	Processor (CPU) power	Memory capacity	Connection capabilities such as Bluetooth, WiFi, NFC and A/GPS	T30 Satisfaction	T21 Satisfaction	Intended Quality	Corrected Improvement Ratio	Sales Advantage	Absolute Weight	Relative Weight
Ease of use	4,1		9	3	9	9	3	3	2,6	2,5	4,1	1,58	1,5	9,7	11,54
Switch speed between the interfaces	4,3		9		9	9			3,1	1,7	4,3	1,39	1,5	8,95	10,65
Visuality (interface)	3,5		9		9				3,1	2,2	3,5	1,13	1,2	4,74	5,64
Internet connection rate	3,8	9	3	9	3	3	1	3	3,3	2,5	3,8	1,15	1,2	5,25	6,25
Variety of applications	3,3		9		3		3		3,1	3	3,3	1,06	1	3,51	4,18
Long battery life	4,1	3	3	9	3	1			2,2	2,4	4,1	1,86	1,5	11,46	13,64
Entertainment platform such as music, video and game	2,8		3		1	3	9		3	2,9	2,8	0,93	1	2,61	3,11
Functionality	3,7	3	9	3	9	3	1	9	3,1	2,2	3,7	1,19	1,2	5,3	6,31
Network performance (calling, being called, data	3,9	9	1	9		1			3,2	2,8	3,9	1,22	1,2	5,7	6,79
Messaging (SMS, MMS, e-mail and instant messaging)	3,8	3	1		1	1	1		3,5	2,4	3,8	1,09	1,2	4,95	5,89
Mobile payment	2,1		3	3	9			9	3	2,7	2,1	0,7	1	1,47	1,75
Map, navigation and location based services	2,7	3	9		9	3	1	9	3,2	2,5	2,7	0,84	1	2,28	2,71
Social media applications	3,7	3	3		3	1	1		3,6	2,8	3,7	1,03	1,2	4,56	5,43
Screen size	3,6			9		3			3,8	2,6	3,6	0,95	1,2	4,09	4,87
Sensitivity of touch screen	4,2		3	9	3	3			2,8	1,8	4,2	1,5	1,5	9,45	11,25
Absolute Importance		184,2	425,37	372,96	402,21	281,46	85,46	126,3							
Relative Importance (%)		9,81	22,65	19,86	21,42	14,99	4,55	6,73							

Fig 3. House of quality

3.1.10 The integration of Kano Model

The eventual purpose of QFD is high level customer satisfaction. It is assumed that each requirement for the service/product has the same influence on the customer satisfaction in this approach where as each requirement does not have the effect in same level while meeting these requirements. In this situation, Kano Model comes up with

effective approach in categorization and comprehension of the customer requirements. According to the influences of each customer requirement on customer satisfaction, different weight values are assigned. The examples from the literature survey show that the integration of Kano Model with QFD provides contribution efficiently to the high level customer satisfaction.

This categorization phase mentioned in Kano Model is carried out via applying Kano questionnaire consisting of one positive and one negative question.

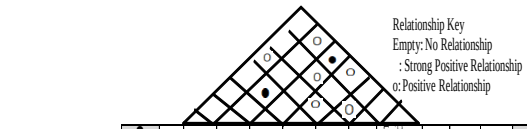
Kano questionnaire is arranged amongst the group who attended before to the QFD questionnaire at the beginning of the study. Then customer requirements for smart phone are categorized properly based on the replies of Kano questionnaire. This process is performed by separating them to the basic, linear and attractive requirements.

Kano improvement parameter (k) is selected ½, 1 and 2 for the basic, linear and attractive requirements respectively. The following formula is executed and improvement ratio (IR) is again calculated afterwards.

$$IR_{cor.} = (IR)^{1/k} \quad (4)$$

At the last stage of integration of Kano Model, absolute importance levels (absolute weight) are calculated by multiplying average importance level, corrected improvement ratio and sales advantage values for each customer requirements. Then absolute weight values are divided by the total value and relative weights (percentage) are obtained. The calculation of relative weights displays the most prominent requirements having priority for the customer satisfaction.

Finally, absolute importance and relative importance values are calculated in order to complete the house of quality after correction due to the Kano Model integration on the application of study. Correlation matrix, formed by the technical QFD questionnaire before, is utilized here to be able to calculate.



Custormer Requirements / Technical Requirements	BASIC NEEDS IN KANO	IMPORTANCE LEVEL	Network technology supported by device	Operating system	Hardware (HW) design	Software (SW) design	Processor (CPU) power	Memory capacity	Connection capabilities such as Bluetooth, WiFi, NFC and A/GPS	T30 Satisfaction	T21 Satisfaction	Intended Quality	Corrected Improvement Ratio	Sales Advantage	Corrected Absolute Weight	Corrected Relative Weight
Ease of use	D	4,1		9	3	9	9	3	3	2,6	2,5	4,1	1,58	1,5	9,72	11,17
Switch speed between the interfaces	D	4,3		9		9	9			3,1	1,7	4,3	1,39	1,5	8,97	10,31
Visuality (interface)	D	3,5		9		9				3,1	2,2	3,5	1,13	1,2	4,75	5,46
Internet connection rate	D	3,8	9	3	9	3	3	1	3	3,3	2,5	3,8	1,15	1,2	5,24	6,03
Variety of applications	D	3,3		9		3		3		3,1	3	3,3	1,06	1	3,50	4,02
Long battery life	D	4,1	3	3	9	3	1			2,2	2,4	4,1	1,86	1,5	11,44	13,15
Entertainment platform such as music, video and game	D	2,8		3		1	3	9		3	2,9	2,8	0,93	1	2,60	2,99
Functionality	T	3,7	3	9	3	9	3	1	9	3,1	2,2	3,7	1,42	1,2	6,30	7,25
Network performance (calling, being called, data transfer etc.)	T	3,9	9	1	9		1			3,2	2,8	3,9	1,49	1,2	6,97	8,02
Messaging (SMS, MMS, e-mail and instant messaging)	T	3,8	3	1		1	1	1		3,5	2,4	3,8	1,19	1,2	5,43	6,24
Mobile payment	H	2,1		3	3	9			9	3	2,7	2,1	0,84	1	1,76	2,03
Map, navigation and location based services	D	2,7	3	9		9	3	1	9	3,2	2,5	2,7	0,84	1	2,27	2,61
Social media applications	T	3,7	3	3		3	1	1		3,6	2,8	3,7	1,06	1,2	4,71	5,41
Screen size	T	3,6			9		3			3,8	2,6	3,6	0,9	1,2	3,89	4,47
Sensitivity of touch screen	D	4,2		3	9	3	3			2,8	1,8	4,2	1,5	1,5	9,45	10,86
Absolute Importance			200,39	437,52	386,31	414,93	285,96	87,03	137,91							
Relative Importance (%)			10,28	22,44	19,81	21,28	14,66	4,46	7,07							

Fig 4. House of quality after integration of Kano model

IV. CONCLUSION

First of all, the findings of the House of Quality have been analyzed, and development areas and necessary technical specifications have been determined. Later on the Kano Model has been included in order to prioritize the significance of customer necessities, and the new House of Quality has been built.

According to the analyses of the House of Quality, "Long battery life" is found to have the most weight with 13.64% relative weight raito amongst customer requirements. "Ease of Use" and "Touch-operated Sceen Sensibility" follow this with 11.54% and 11.25% relative weight ratios.

When looked at the correlation of customerrequirements and technical requirements, "Long Battery Life" is found to be possible via improvements in hardware design. Giving more space to the battery will increase its capacity. Locating the antenna at the right position will also improve battery life, since the mobile phone will lose less energy in order to communicate with the base station.

When the first House of Quality is examined in detail, "Operating System" is seen to have 22.65% relative importance ratio, which is the highest ratio amongst technical properties. "Software Design" is the second with 21.42% relative importance ratio, which is followed by "Hardware Design", "Processor Power", "the Technology of the Supported Network", "Connection Support, such as Bluetooth, WiFi, NFC, A/GPS", and "Memory Capacity".

So less is changed after including the Kano Model to the application. “Long Battery Life” and “Ease of Use” are the first and the second ratios, with the percentages of 13.15% and 11.17%. other customer requirements are in the same order with the QFD findings. “SMS” is in the category of the Basic Needs in Kano classification, rather than “Internet Connection Rate” in QFD. This indicated the increase of the characteristic of SMS, which necessitates putting more effort in supplying this attribute.

When the second House of Quality, which includes the Kano Model, is examined in detail, “Operating System” is seen to have 22.44% relative importance ratio, which is the highest ratio amongst technical properties. “Software Design” is the second with 21.28% relative importance ratio. Although relative importance ratios differ a little, the sequence of the basic QFD approach still stays the same. “The Technology of the Supported Network”, and “Connection Support, such as Bluetooth, WiFi, NFC, A/GPS” have higher relative importance ratios. Other technical characteristics show slight declines in their relative importance ratios.

New smart phones will be designed according to the results of the QFD Quality Management Technique, supported by the Kano Model. The phones are suggested to have the below mentioned properties as a result of this study:

- The usage of newer versions of Google Android operating system
- The design of a user friendly interface
- The addition of shortcuts to the main screen (like Google)
- Installing a higher capacity battery, preserving the hardware design
- Higher touch-screen sensitivity via IPS technology
- The use of a larger screen in hardware design (minimum 4 inch)

Smart phones have been analyzed from the customers’ point of view, using QFD and the Kano Model, and the most important specifications have been determined. While technical necessities have been determined by QFD, the classification of the customer requirements has been made by intergration the Kano Model to the QFD study.

In the study technical specifications are given under general titles in order to make them more interpretable and easier to establish HoQ matrix. Instead of this approach, these technical features can be rearranged in detail for the further research thereby reducing target features to more specific state. In this way work load is increased by this action, but the engineers can understand better how the customer requirements are satisfied effectively.

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REFERENCES

[1] X. Zheng, and P. Pulli, “Improving mobile services design: a QFD approach”, Computing and Informatics, Vol. 26, 2007, pp. 369–381.

[2] E. Ronney, P. Olfe, and G. Mazur, “Gemba research in the Japanese cellular phone market”, Public Presentation, QFD Institute, 2000. Available: http://www.mazur.net/works/nokia_gemba_research_in_japanese_cellular_market.pdf

[3] M. Valtasaari, “Design for customer needs: Utilization of quality function deployment in product development”, Department of Industrial Engineering and Management (MSc. Thesis), Lappeenrannan University of Technology, Finland, 2000.

[4] M. Hussain, L. Tsironis, and M. M. Ajmal, “A QFD strategy for improving customer satisfaction: case study of telecom companies of Pakistan”, Asian Journal on Quality, Vol. 12, 2011, pp. 282-295.

[5] B. M. West, and J. Olhager, “The house of flexibility: using the QFD approach to deploy manufacturing flexibility”, International Journal of Operations & Production Management, vol. 22, 2002, pp. 50-79.

[6] M. Haverila, “Cell phone usage and broad feature preferences: A study among Finnish undergraduate students”, Telematics and Informatics, Vol. 30, 2013, pp. 177-188.

[7] E. Sutherland, “Counting customers, subscribers and mobile phone numbers”, Info, Vol. 11, No. 2, 2009, pp. 6-23.

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