ANTICANCER EFFECTS OF DIFFERENT EXTRACTS OF VARIOUS ANTRODIA CINNAMOMEA TYPES ON HUMAN LIVER HEPG2 CELLS AND ANALYSES OF COMPOSITIONS AND BIOACTIVITIES

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Abstract- Antrodia cinnamomea (AC) is a medicinal fungus found locally in Taiwan. Many studies have confirmed that AC is rich in triterpenoids, polysaccharides and other nutrients that may carry functional properties such as detoxification, anti-inflammatory activity, liver function improvement and anti-cancer activity. White AC is thought to be relatively rare and is therefore expensive; it has a greater content of functional compounds than regular forms of AC. Thus, this study was performed in order to develop an ideal culture medium and to compare the contents of bioactive compounds, including triterpenes and polysaccharides, and medicinal functions, such as effects on free-radicals (DPPH) and anti-B liver cancer cells (MTT assay) of the regular form (red AC), the white variant of AC, wild-type red AC in a Petri-dish culture medium, and Basswood AC. The study results showed that the homemade medium enhanced the crude triterpenoid content of mycelia and basidiomatal formation of AC under Petri-dish solid-state fermentation. The polysaccharides contents of regular and white AC were higher in the homemade medium than in the commercial medium. The antioxidant effects (DPPH) of white and red AC in the Petri-dish culture were greater than that of Basswood white AC (culture growth only for 1 month). In addition, it was found that addition of peptone to the culture medium increased the contents of DeEA, DeSA, antcin B and antcin H. Anti-B cancer cell tests showed that approximately 50% inhibition was achieved at 62.5 μg/mL. The wild-type AC fruiting bodies extract concentration was higher than 125 μg/mL, and the anti-B cancer cell effect was over 80%. The results showed that wild-type red AC also exhibited good anti-cancer effects. However, these fungi are not easy to obtain, and 2–3 years are required for the development of fruiting bodies; in addition, other issues must be overcome during culture, such as infection. This study demonstrated the development of a suitable culture medium for solid-state fermentation of AC products that confer protective effects against B liver cancer cells, which has potential applications in the healthcare industry.

Keywords- Antrodia cinnamomea, HPLC; Triterpenoids, Solid-state fermentation, MTT assay.

I. INTRODUCTION

Chronic hepatitis or detoxification leads to severe liver injury. The damaged hepatocytes are initially denatured, and subsequently undergo fibrosis and necrosis, this process eventually leading to hepatoma [1]. Antrodia cinnamomea (AC) is a medicinal fungus locally available in Taiwan. Many studies have confirmed that AC is rich in triterpenoids, polysaccharides and other nutrients that may carry functional properties such as antioxidant activity [2], antiviral effects [3], anti-inflammatory activity[4], liver function improvement effects, and anti-cancer activity[5]. Fruiting bodies of AC are yellow-orange to red-brown in most cases; however, a white variant also occurs in the natural environment. White AC is thought to be relatively rare and is expensive; it has a greater content of functional compounds than the regular form of AC.

Thus, this study was performed in order to develop the ideal culture medium and to compare the bioactive compounds, including triterpenes and polysaccharides, and medicinal functions, such as effects on free-radicals (DPPH) and anti-B liver cancer cells (MTT assay) of the regular form (red AC), the white variant of AC, wild-type red AC in a Petri-dish culture medium, and Basswood AC.

II. DETAILS EXPERIMENTAL

2.1. Fungal strain and chemicals

A. cinnamomea BCRC 35398 was obtained from the Food Industry Research and Development Institute (Hsinchu, Taiwan). White AC was obtained from Dr. Yen's laboratory (Meiho University). Wild-type AC was collected in Chiayi (from the Alishan mountain, which is of approximately 1500 meters in height). The strains were inoculated and maintained in potato dextrose agar (PDA) at 26°C for approximately 15 days, and stored in a refrigerator at 4°C. The abbreviations used in this paper to represent different types ofAC are asfollows: BWAC, Basswood white AC; HMWAC, homemade medium white AC; CMWAC, commercial medium white AC; HMRAC, homemade medium red AC in a15-cm Petri dish; HMNTAC, homemade medium native-type AC; and NTAC, native-type AC. Acetonitrile (ACN, AE0627), methanol and perchloric acid were obtained from Echo Chemical Co.; fetal bovine serum (FBS, 10437) and Dulbecco's modified eagle medium (DMEM, 12800-017) were obtained from Gibco. Dextrose powder, gallic acid, phenol, sodium bicarbonate and dimethyl sulfoxide (DMSO) were purchased from J.T. Backer; 2,2-diphenyl-1-picrylhydrazyl (DPPH) and vanillin were obtained from ACROS (New Jersey, USA); glacial acetic acid was obtained from Wako-Chem. Co. (Japan); and potato dextrose agar plus and potato dextrose were obtained from Hui-dongfeng Co. For high-performance liquid chromatography (HPLC), a UV-Vis detector L-2420 was obtained from HITACHI, and a HPLC column (Hypersil GOLD C18, 250 mm × 4.6 mm) and a microinjector (Finnpipette F3) were obtained from Thermo Co. Triterpenoid indicators for 8 standard compounds of AC were obtained from Dr. Cheng's laboratory (National Pingtung University, Taiwan).

2.2. Growth of A. cinnamomea

The PDA medium consisted of the following components (w/v): potato 25 g, glucose 30 g, agar 12 g in 1 L distilled water. The culture medium was autoclaved at 15 psi, 121°C for 20 min. A 0.3 × 0.3 cm2 agar blot of AC was placed on a 90 × 20 mm Petri dish containing 23 mL PDA medium. Strain BCRC 35398, red, white and natural-type AC were grown in an incubator at 28°C.

2.3. Sample preparation and extraction

Samples of AC were harvested at 1, 2 and 3 months of age. After growth, AC samples were placed in a drying oven at 50°C for 2–3 days. White and natural-type AC samples were freeze-dried before extraction and analysis.

2.4. Triterpenoids standard compounds of A. cinnamomea

Triterpenoids indicators for 8 standard compounds [antcin A, antcin B, antcin C, antcin H, antcin K, dehydrosulphurenic acid (DeSA), dehydroeburicoic acid (DeEA) and 1,4-dimethoxy-2,3-methylenedioxy-5-methylbenzene (DMMB)] were used for comparative analysis of samples of mycelium or fruiting bodies of AC. These benzenoids were of a purity of >98%.

2.5. Determination of total polysaccharides content

For all samples, 100 mg of AC powder were suspended in 1 mL distilled water. The standard curve of linear regression was obtained from the absorbance of different concentrations of glucose solution. The total polysaccharides content in the culture medium was determined using a phenol–sulfuric acid assay according to Hsieh et al. [6].

2.6. Assay of crude triterpenoids content

The crude triterpenoids content assay was modified from that described by Yanget al. [7].Samples of dried mycelia or fruiting bodies of AC were extracted with 10 mL of 95% ethanol for 72 h. After removal of the precipitate by centrifugation at 3000 ×g for 5 min, the supernatants were dried at 43°C under a vacuum, then mixed with 400 μL 5% (w/v) vanillin–acetic acid solution; 1 mL of perchloric acid was also added, following which the solution was mixed and incubated at 60°C for 15 min. Then, the mixed solution was cooled and diluted to 5 mL with acetic acid. The absorbance was detected at 548 nm in a spectrophotometer. The content of crude triterpenoids was calculated on the basis of a standard curve prepared using ursolic acid.

2.7. DPPH free-radical scavenging activity assay

Thefree-radical scavenging activity assay was performed according to a method modified from Wang et al. [8]. Dried samples of mycelia or fruiting bodies of AC were extracted with 10 mL 95% ethanol for 24 h, and the extraction was assisted by successive sonication for 30 min using a Delta DC400H sonication cleaner. Samples were centrifuged at 3000 ×g for 5 min, and the resulting supernatants were freeze-dried and re-dissolved in 1 mL 95% ethanol. In the first series, each AC sample was mixed with 1 mL freshly-prepared ethanol solution of 0.2 mM DPPH. The reaction mixture was vortexed vigorously for 1 min and kept in the dark at 25°C for 10 min. The absorbance of the resulting solution was measured spectrophotometrically at 517 nm against the blank. Ascorbic acid dissolved in ethanol was used as the positive control. The capability to scavenge DPPH free-radicals was calculated using the following equation:

Inhibition ratio (DPPH scavenging effect) (%) = $100-[(A_{sample}/A_{control}) \times 100]$

where in $A_{control}$ is the initial concentration of stable DPPH radicals without AC and A_{sample} is the absorbance of the remaining concentration of DPPH free-radicals in the presence of samples of AC. All results presented were the average of triplicate analyses.

2.8. HPLC analysis of A. cinnamomea

Samplesof dried mycelia or fruiting bodies of AC were extracted with 10 mL 99.95% methanol for 48 h, and the extraction was assisted by successive sonication for 30 min using a Delta DC400H sonication cleaner. Samples were centrifuged at 13,000 ×g for 2 min, and the supernatants were filtered using a 0.2-μm filter. The method of triterpenoid analysis was modified from Yang et al. [9]and Wu et al. [10]. HPLC was performed on a Hitachi L2420 series with a reverse-phase column (Hypersil GOLD C18, 250 mm × 4.6 mm, Thermo) under 254 nm UV detection. The mobile phase was eluted at a flow rate of 1 mLmin-1 with a linear solvent gradient elution of A (H2O) and B (acetonitrite), with the following gradient program: 0–10 min, 30–30% B; 10–40 min, 30–50% B; 40–50 min, 50–60% B; 50–53 min, 60–90% B; 53–63 min, 90–90% B; 63–90 min, 90–100% B. HPLS was performed at room temperature, with an injection volume of 20 μL.

2.9. Cell line and culture

Human cancer cell line HepG2, a human liver carcinoma, was obtained from Dr. Shi's laboratory

(National Pingtung University, Taiwan). The cancer cell line was maintained in DMEM medium containing 10% FBS, 2 mM glutamine and 1% penicillin. The cells were cultured at 37°C in a 5% CO_2 incubator for one week.

2.10. Cytotoxicity analysis by MTT assay

HepG2 cells were plated in 96-well plates (1 × 10^4/well) and incubated for one day.The viability of HepG2 cells was examined following treatment with 100 μL of differing concentrations (0, 7.8, 15.6, 31.25, 62.5, 125 and 250 μg/mL) of AC sample extracts for 72 h. The medium was removed and cells were washed once with PBS buffer then incubated in 200 μL MTT solution (0.5 mg/mL) without FBS in DMEM for 2 h at 37°C. Finally, the MTT solution was removed and 100 μL DMSO (100%) were added to each well. The absorbance was measured at 570 nm using a microtitre plate reader [12].

2.11. Statistical analysis

Variations between experiments were estimated from standard deviations, and the statistical significances of changes in physiological parameters were estimated by analysis of variance (ANOVA) using Tukey's multiple comparison test. On all graphs presented, means in each row followed by the same letter are not significantly different ($P<0.05$). All data were obtained from three replications.

III. RESULTS AND DISCUSSION

3.1. Determination of total polysaccharide and triterpenoids contents

The study results showed that the homemade medium enhanced the crude triterpenoids content of mycelia and basidiome formation of AC under Petri-dish solid-state fermentation. The polysaccharides contents of regular and white AC in homemade medium were higher than those in commercial medium (Fig. 1A). The total triterpenoids content of HMRAC (15-cm Petri dish) was the highest of all samples at 67.03 mg/g, followed by HMWAC+P (peptone) with a content of 51.22 mg/g and CMWAC with a content of 49.47 mg/g. BWAC and BWAC (in 4□ for 1 day) had the lowest triterpenoids contents, at 25.15 and 24.13 mg/g, respectively (Fig. 1B).

3.2. HPLC analysis of A. cinnamomea

HPLC analyses were performed on basidiomes and mycelia samples extracted from Petri-dish-grown homemade and commercial medium cultured and Basswood white AC (Fig. 2A–D). Our results showed that the samples cultured in homemade medium contained more antcin K than those in commercial medium; the dehydroeburicoic acid (DeEA) content in samples cultured in homemade medium was approximately185 mAU, which was nearly 3.7 times higher than the content in samples cultured in commercial medium (approximately 50 mAU). The antcin A,Band H,and DeSA and DeEA contents were significantly higher in samples cultured in homemade medium with added peptone, which demonstrated that the addition of peptone could effectively accelerate the formation of basidiomes and enhance the production of bioactive compounds fromAC.

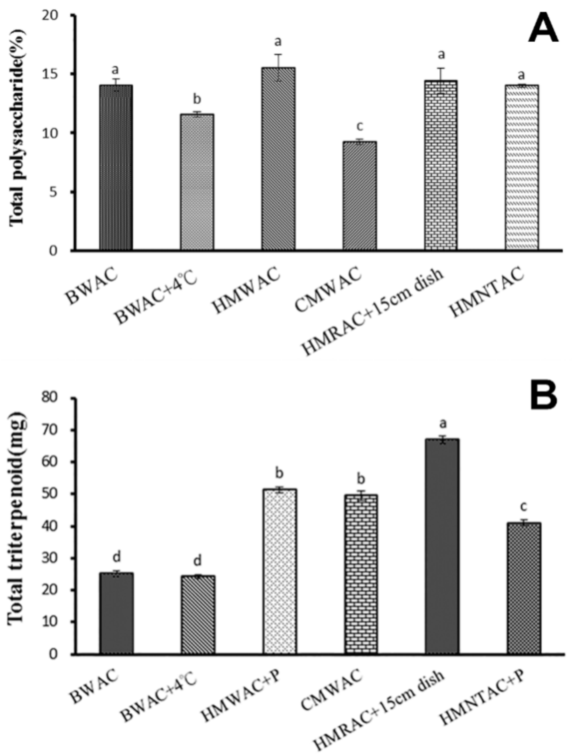

Fig.1. Comparisons of the total (A) polysaccharides and (B) triterpenoids contents of different samples extracted from A. cinnamomea.

Table1: Comparisons of eight triterpenoid indicators (%) in 1 g of extracted samples from different types of A. cinnamomea by HPLC analysis.

Triterpenoid 8 indicator /samples	A	B	C	D	E	F	G
Antcin A	0.03	nd	0.08	0.06	0.01	1.46	0.17
Antcin B	nd	0.03	0.30	0.60	0.04	9.90	0.58
Antcin C	0.05	0.03	0.05	0.09	nd	3.28	0.36
Antcin H	nd	0.04	0.34	0.29	nd	4.47	0.73
Antcin K	nd	0.08	0.02	0.06	0.03	2.99	nd
DMMB	nd	0.14	0.16	0.63	0.18	1.95	0.57
DeSA	1.02	0.79	0.97	1.62	0.93	3.67	1.40
DeEA	0.74	0.77	1.08	1.57	0.88	0.92	0.39
Total	1.83	1.87	2.98	4.93	2.07	28.65	4.21

A: BWAC (Basswood white AC); B: HMWAC (homemade medium white AC); C: HMWAC (homemade medium white AC); D: HMRAC (homemade medium red AC on a 15-cm Petri dish); E: HMNTAC (homemade medium native-type AC); F: NTAC (native-type AC); G: CMWAC (commercial medium white AC); nd: not detectable.

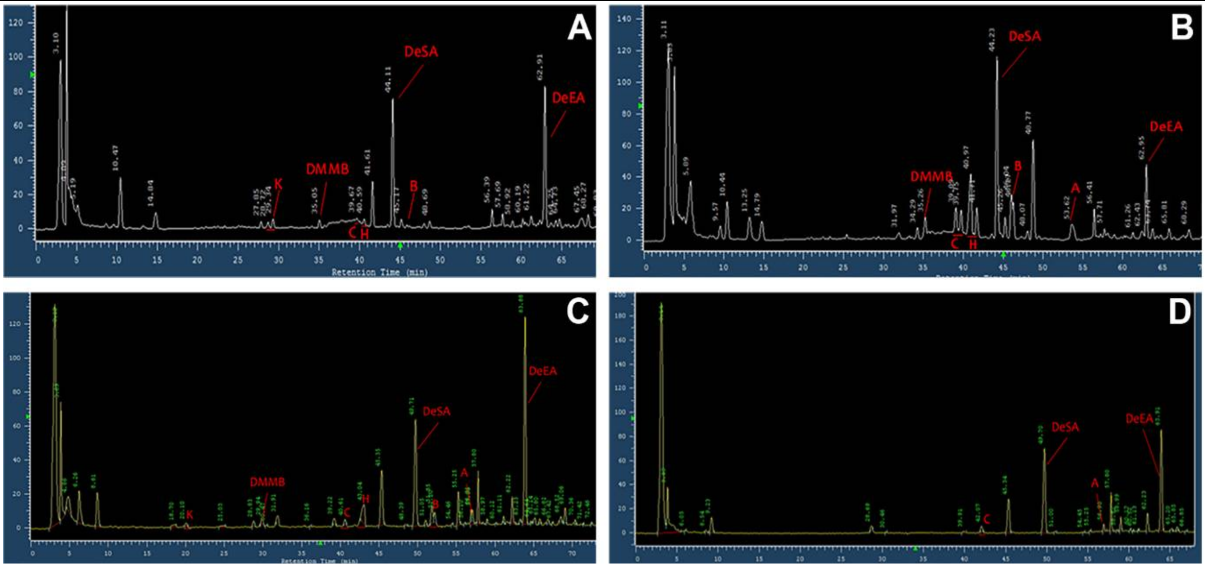

Fig.2. Triterpenoid indicator contents of 8 standard compounds from (A) HMWAC, (B) CMWAC, (C) HMWAC+P, and (D) BWAC grown for 1-2 months.

3.3. DPPH free-radical scavenging activity assay

The antioxidant activity in terms of 0.2 mg DPPH free-radical scavenging ability was determined. Figure 3 shows the results for BWAC, BWAC+4°C, HMWAC, CMWAC, and HMRAC+15-cm Petri dish, and vitamin 10 at 25 ppm. The DPPH free-radical scavenging activity was of the following order: vitamin C 25 ppm, HMWAC (72.9%), CMWAC (69.64%), HMRAC+15-cm Petri dish (65.10%), BWAC (25.99%), BWAC+4°C (13.58) (Fig. 3). Our results showed that the DPPH activities of white AC under homemade Petri-dish culture and red AC cultured in commercial medium were greater than the activity of Basswood white AC.

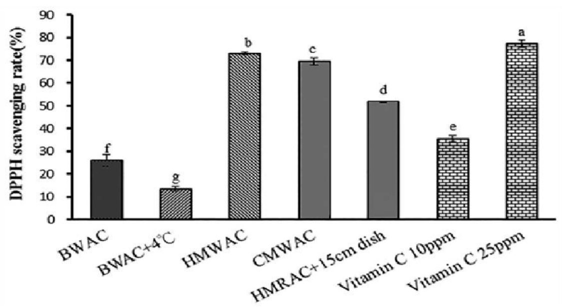

Fig.3. Comparison of antioxidant activities of different extracts of A. cinnamomea.

3.4. MTT-based cell viability assay of different extracts of A. cinnamomea in HepG2 cells

The MTT assay results showed that the inhibitory effect on human liver cell line HepG2 was increased upon treatment with 7.825,15.625,31.25,62.5 and 125 μg/mL of extracts of various types of AC, and all types of AC exhibited similar levels of inhibition at a concentration of 62.5 μg/mL (Fig. 4A). However, the inhibitory effects of CMWAC and HMRAC+15-cm Petri dish decreased upon increased concentration to 125 μg/mL (Figs. 4B & 5). The above-described anti-B cancer cell tests showed that approximately 50% inhibition was achieved at a concentration of 62.5 μg/mL; however, the concentration of wild-type AC fruiting bodies extract was higher than 125 μg/mL, and the anti-B cancer cell effect was over 80%.

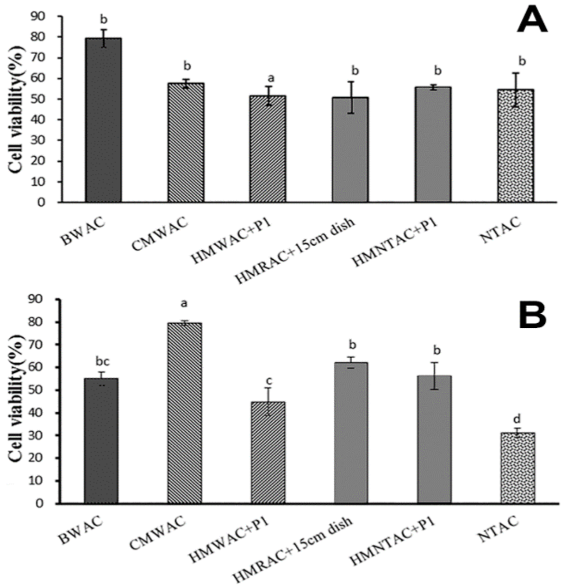

Fig.4. Comparison of cell viability (%) of human liver HepG2 cells incubated with (A) 62.5 μg/mL and (B) 125 μg/mL of different extracts of A. cinnamomea for three days.

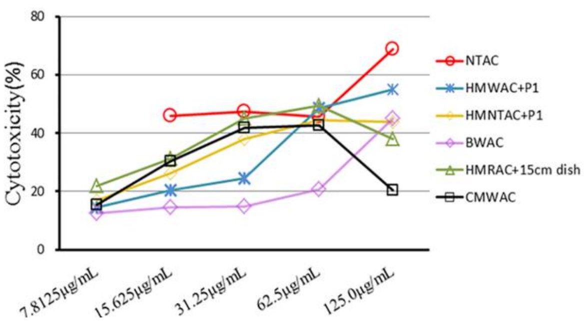

Fig.5. Inhibition effects of different concentrations of extracts of various types of A. cinnamomea against HepG2 cells.

CONCLUSIONS

This study evaluated 8 triterpenoid indicators in different AC extracts in artificial culture medium (homemade medium) modified from commercial medium by HPLC and compared the compositions and bioactivities of regular and white AC. AC has attracted a great deal of attention in Taiwan in recent years owing to its valuable medicinal properties. At present, one of the chief problems is AC cultured on wood Cinnamomumkanehirai Hay) that it takes 2–3 years or more for fruiting bodies to form. In order to enhance production efficiency, control of environmental conditions and modification of the medium composition are required. This study demonstrated the development of a culture medium that resulted in higher contents of triterpenoids, polysaccharides and other bioactive components of AC that may be useful in various health-related products, and hence has considerable potential for application in the healthcare industry.

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THE ROLE OF ECONOMIC CITIZENSHIP EDUCATION IN ADVANCING GLOBAL CITIZENSHIP

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Abstract- This article focuses on how to provide children and youth with the appropriate skills and capabilities required to create a more equal and sustainable world for future generation. It presents the concept of Economic Citizenship Education and the importance of combining financial social and livelihood education for the empowerment of children and youth throughout the world. Throughout the article this concept is linked to Global citizenship. Education for sustainable development is related to Global Citizenship Education, focusing on create and constructive solutions to present and future global challenges which created more sustainable and resilient societies. Development Education is also closely linked to Global Citizenship Education because it raises awareness of the rights and responsibilities of citizens to ensure a more just and equal world. The goal of the child and youth finance movement is to empower children and youth so they can reach their potential as responsible and engaged economic citizens. Global citizenship is interrelated with economic citizenship because they both emphasise the importance of awareness and responsibility for one's actions at local, national and international levels. Global Citizenship Education, Education for sustainable Development and Development Education, Economic Citizenship Education is focus on global inclusion, awareness, respect and sustainability. However, it has a focus on financial capability and economic empowerment since full economic citizenship can improve economic and social wellbeing. Reduce income and asset poverty and lead sustainable livelihoods for children and youth. Social Education a central component of Economic Citizenship Education, has the capacity to improve some learning areas and build capabilities in present and future generation, allowing them to better understand. value and contribute to the world in which they live.

Key words- EconomicCitizenship Education (ECE); Child and Youth Finance International(CYFI); Financial Literacy(FL); Social Education(SE); Global Citizenship(GC).

Introduction

Adversity and deprivation are experienced by millions of children around the world (UNICEF, 2016). These children are unable to build a sustainable livelihood because they lack many foundational skills and prospects of finding meaningful employment. They may also be working their way through school or financially supporting their families. Children and youth need to be provided with the appropriate capabilities and skills in addition to being offered control over their own finances in order to be able to thrive within the current economy (CYFI, 2016c: 9). Children and Youth Finance International (CYFI) follows the United Nations (UN) definition of 'youth' as those between the ages of 15 and 24 years, without prejudice to other definitions by UN member states. Children are defined as those under the age of 18 and a 'young person' as someone between the ages of 10-24.

This article discusses the role of finance in striving for a more equal and sustainable world for the next generation and argues that the combination of financial, social and livelihoods education is vital for successfully empowering children and youth. These educational components, and the concept of economic citizenship, are inextricably linked to the achievement of Global Citizenship and the Sustainable Development Goals (SDGs). Therefore, it is important that the concept and practice of Economic Citizenship Education (ECE) becomes part of the contemporary discourse on education and youth development.

Children and Youth Finance International (CYFI)

Education in the field of global citizenship and sustainable development has been advocated for, researched and promoted by organisations such as Oxfam, United Nations Children's Fund (UNICEF), United Nations Educational, Scientific and Cultural Organisation (UNESCO) and others (UNICEF, 2012; Oxfam, 2015; UNESCO, 2015; UNESCO, 2016). CYFI opts for an approach that combines many of these educational frameworks but also offers the additional angle of finance and entrepreneurship. CYFI's mission, and that of the Child and Youth Finance Movement is 'to empower all children and youth worldwide by supporting them in realizing their potential as full economic citizens' (CYFI, 2016c: 9) through financial inclusion as well as financial, social and livelihoods education. Currently there is a global focus on creating a savings culture, improving saving habits, and creating employment opportunities for young people. Consequently, financial capability and sustainable livelihoods for children has been a key focus of the agendas of national and regional authorities, civil society organisations, and financial institutions (Population Reference Bureau, 2013).

There are currently 1.8 billion young people in the world, representing 25 per cent of the global population, with 87 per cent of this youth population residing in developing countries. These figures are projected to increase in the coming years with both challenges and opportunities for youth development (UNCDF, 2013; UNFPA, 2014). The challenges include the fact that, while children make up around a third of the global population, almost 47 per cent of those struggling to survive on less than $1.25 a day are 18 years old or younger (Coalition of Partners Working to End Poverty, 2015). There are also 58 million children around the world that are not enrolled in school, which threatens their ability to sustain themselves in the future (World Bank, 2014).

Additionally, about 225 million youth, or 20 per cent of all youth in the developing world, are 'NEET' (i.e. not in education, employment or training) (UN Youth, 2014). The youth NEET rate for countries in the Organisation for Economic Co-operation and Development (OECD) in 2014 stood at 18 per cent (ILO, 2016: 18), while the official global youth unemployment rate in 2015 was estimated at 13.1 per cent (ILO, 2015: 15). Within their economic and social environment, education plays a vital role in providing these young people with the financial, social and livelihood competences and opportunities needed to thrive and prosper. It is imperative that education delivers meaningful and useful skills to children and youth, and that it remains an integral part of their personal and professional development. If children acquire the skills and experiences of managing financial resources from an early age onward, it will enhance their awareness of financial risks, lower their economic vulnerability and allow them to make more responsible financial decisions (Whitebread and Bingham, 2013). In addition, the inclusion of social and citizenship education ensures that young people develop financial capabilities that are rooted in socially responsible attitudes and behaviours (CYFI, 2016c).

Despite the increased attention for the development of entrepreneurial and employability skills for children and youth by national and regional authorities, multilateral institutions, and civil society organisations, youth unemployment remains a leading problem facing governments around the world (ILO, 2016). In addition, the need for both a secure asset base and responsible financial management were reinforced by the recent financial crisis, in which children and youth proved to be a vulnerable age group that was far more likely than adults to be financially excluded or prone to financial exploitation (Demirguc-Kunt, Klapper, Singer and van Oudheusden, 2015). Increasing the entrepreneurial and employability skills of children and youth, to enable them to secure sustainable livelihoods, is an essential aspect of financial inclusion and economic citizenship. Moreover, by improving social and livelihoods education for children and youth, socially and environmentally responsible behaviours are cultivated at an early age, encouraging more socially accountable and sustainable enterprise. The social education that complements financial and livelihoods education empowers youth and makes them aware of their own rights and responsibilities, as well as those of others. The impact of financial, social and livelihood education therefore not only reaches the lives of individuals but their whole community as well by encouraging new generations to become financially capable and grow up to be responsible investors, entrepreneurs and economic citizens.

Global Citizenship (GC)

In a globalised world, individuals are becoming increasingly interconnected and are consequently experiencing wider conceptions of community and a common humanity. A globalised world ushers in the notion of Global Citizenship, which is defined as 'awareness, caring, and embracing cultural diversity while promoting social justice and sustainability, coupled with a sense of responsibility to act' (Reysen and Katzarska-Miller, 2013: 860). Similarly, UNESCO defines Global Citizenship as a 'political, economic, social and cultural interdependency and interconnectedness between the local, the national and the global' (UNESCO, 2014: 14). Oxfam sees a global citizen as someone who 'is aware of the wider world' and 'works with others to make the world a more equitable and sustainable place' and 'takes responsibility for their actions' (Oxfam, 2015: 5).

These definitions of Global Citizenship all contain a perspective in which citizenship demands that individuals not only take responsibility for their own actions but also for the world around them. Global citizens have an obligation to understand how the world works and to contribute to social and economic sustainability through active community engagement from local to global levels (UNESCO, 2014: 14). Global Citizenship places greater responsibility for the world in the hands of ordinary citizens to ensure it becomes central to the political and economic development of society.

An increased interest in global citizenship has resulted in growing attention for education frameworks that build citizenship competencies, with the additional implications it has for policy, teaching and learning. According to UNESCO, Global Citizenship Education (GCE) 'is a framing paradigm which encapsulates how education can develop the knowledge, skills, values and attitudes learners need for securing a world which is more just, peaceful, tolerant, inclusive, secure and sustainable' (UNESCO, 2014: 9). GCE demonstrates that education is vital in understanding and solving global issues through various political, social, cultural, religious, economic and environmental viewpoints.

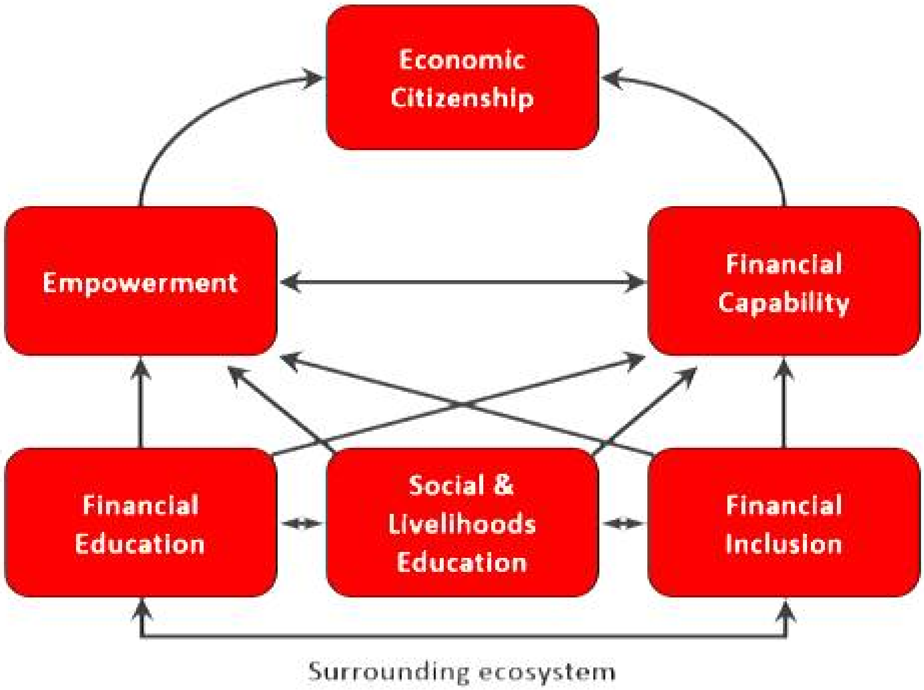
GCE emphasises that developmental challenges are applicable to all countries and all people.

DE offers an educative perspective that focuses on international development and human rights everywhere. It promotes the voices and viewpoints of those who are 'excluded from an equal share in the benefits of human development internationally' and creates the opportunity to reflect on 'international roles and responsibilities with regard to issues of equality and justice in human development' (Ibid: 6).

CYFI's Model of Economic Citizenship

The current market economy requires economic citizens to possess financial knowledge, economic awareness and social agency, especially given its tendency to create gross social and economic inequalities. Full economic citizenship represents a comprehensive concept that encompasses a broader range of social and gender elements to complement prevailing economic norms, ensuring a more inclusive economic system for everyone. Economic citizenship is built on empowerment, inclusion and capability, which are concepts greatly enhanced by education. Empowerment is conceived to encompass social, economic and gender elements, involving a greater sense of confidence and freedom to participate effectively in the economy, the household and the wider community. This is the result of improved knowledge and skills, along with the tearing down of socio-economic barriers. In addition, financial capability encompasses access to finance and markets, as well as the ability to take advantage of economic opportunities. ECE can help disadvantaged people reach their full potential as economic citizens and eventually lead to reduced inequality and improved financial sustainability. All children and youth should have the opportunity to become better informed, capable and responsible economic citizens. However, there are many systematic barriers to education, financial inclusion and civic participation that prevent young people from achieving their full potential. To overcome this, systemic change is needed to foster greater economic citizenship from the local to the global level. Some of the essential building blocks of a model of economic citizenship can be seen in Figure 1.

Figure 1. Child & Youth Finance International (CYFI) Model of Economic Citizenship (CYFI, 2016c).



Economic Citizenship

- Reduced income and asset poverty;
- Economic and social engagement;
- Sustainable livelihoods;
- Economic and social well-being;
- Rights for and responsibilities to self, family, and others.

CYFI sees ECE as 'a holistic approach to financial education, complementing it with a focus on life skills and livelihoods' (CYFI, 2016b: 9) in which the most striking aspect of this educational approach is its social emphasis. The three main components of this model are: financial education, social/life skills education and livelihoods education. Financial education encompasses the 'instruction and/or materials designed to increase financial knowledge and skills' (CYFI, 2016c: 13). Social education is the 'provision of knowledge and skills that improve individuals' understanding and awareness of their rights and the rights of others' (CYFI, 2016c: 13). This could also include environmental stewardship and sexual and reproductive health. Life skills are part of social education and entail problem solving, critical thinking, and interpersonal skills. Livelihood education improves one's ability 'to secure a sustainable livelihood through skills assessment and a balance between developing entrepreneurial and employability skills' (CYFI, 2016c: 13). The content of these different components of ECE can be seen in the summarised table in Figure 2, with a suggested division along specific age segments.

Figure 2. Economic Citizenship Education Learning Framework (Summary) (CYFI, 2016c).

	Financial education	Social Education	Livelihoods education
Level-1 0-5 Years	Value of money, prices, savings, belongings.	Emotions, consequences, health/safety, compassion.	Career interests, professions, entrepreneurship, goals, initiative, problem solving skills, teamwork, taking advice, avoiding hazards.
Level-2 6-9 years	needs and wants, savings plan, rewards, recognize banks and financial services.	Children's rights, responsibilities, respect for others, rules, listening skills.	
Level-3 10-14 years	Informed consumer, short vs. long term planning, financial risks, effects of advertising.	Express opinions, teamwork, research skills, appreciation for life-long learning.	Vocations, opportunities, action plan, self-discipline, perseverance, communication.
Level-4 15+years	Negotiation skills, Purchasing power, interest rates, financial crimes.	Social justice, time management, relationships, leadership.	Wages, Capital needs, marketing, employability, coping with change, management skills.

To ensure the awareness of social and financial matters, it is important to make sure that children and youth are financially included and are exposed to quality ECE. By empowering and engaging young people with this learning content, they are able to 'lower the risk of exploitation and build a strong asset base, complemented by financial literacy, social values and entrepreneurial skills' (CYFI, 2016a: 10). Social education, therefore, plays an important role in 'steering children away from financial behaviours and attitudes that may negatively affect not only personal well-being but also that of the wider community' (CYFI, 2016b: 22). It is important to emphasise social and livelihood issues alongside financial education. These issues could include the disparity between rich and poor, resource conflicts, the role of marketing and consumerism in modern society, the human and environmental impact of corporate irresponsibility, and the reality that moral behaviour and economic success are not mutually exclusive. The ultimate goal is to allow these children and youth to become more responsible and engaged global economic citizens to create a more sustainable world with less inequality and injustice.

Both the individual and the local community play vital roles in addressing and contesting social, political and economic structures from the bottom up. This is why ECE can inform individuals and equip them with the skills that are necessary for contesting these structures, particularly in the financial and economic realm.

Making children and youth aware of the world around them will not immediately challenge political, economic and social structures. However, a holistic approach to education that involves core elements of ECE is certainly a step in the right direction, cultivating the minds of future generations of economic and global citizens.

CONCLUSION

The political and economic decisions of world leaders today and tomorrow not only dictate the future of world economies but also the future sustainability of societies and the environment. It is therefore extremely important that these decisions are made in a holistic and responsible manner, balancing financial, social and environmental considerations. ECE is criticalto the development of global citizenship by creating an environment where children and youth are able to fully realise their social and economic potential and contribute to community development, without discrimination of any kind. These are the essential economic citizenship competencies that will provide the foundation for the next generation of political, business and social leaders.

In a world where poverty and inequality continue to be exacerbated by short-sighted, profit maximising policies and practices, the expansion of ECE can play a significant role in equipping young people with the skills and attitudes needed to be financially prudent, socially conscious and ethically responsible in business and relationships. However, improvements to the current market economy and political environment will require more than just the further exposure of young people to ECE through community initiatives and public school curricula. Regulatory policies, as well as greater adherence to socially and environmentally responsible practices within the corporate sector, are also central to the development of a more sustainable and ethical economic system. It is clear that pressing political and economic problems cannot be solved at the individual level alone and that greater systemic change is also needed to advance economic citizenship for all peoples, at the local, national and international level.

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DETERMINATION OF TRAFFIC SAFETY WITH METHODS ALTERNATIVE TO TRADITIONAL METHODS

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Abstract- Every year, hundreds of thousands of people die in traffic accidents and millions are injured worldwide. In Turkey, more than 5 thousand people die in traffic accidents and 200 thousandpeople get serious injured every year. When indirect losses in the society (disabilities occurring as a result of accidents, social and psychological pain caused by deaths or injuries) are also added to the great economic losses, which are caused by these accidents, it is obvious that no countries can be indifferent to traffic accidents.Traditionally, the numbers of casualties and accidents are explained with the proportional terms such as the number of casualties per kilometer traveled, per the number of registered vehicles or per population. However, these proportions cannot help us so much to examine the degree or level of the road traffic safety. Especially over the recent years, several indicators have started to be determined for examining the factors that influence the accidents and making comparison easily. Indicators, which provide a more detailed view, may carry the advantage of determining the problem before the results of the accidents.Together with this study, the factors which influence the transportation safety of 81 cities in Turkey were firstly analyzed for 2010 through the Data Envelopment Analysis (DEA). After the determination of the efficiency of the cities with this analysis, they were put in order with the Super-efficiency (Andersen and Petersen-AP) method. Secondly, variables were analyzed with the Analytical Hierarchical Process (AHP) and cities were put in order. Then, the city orders were compared to the orders defined by the traditional method. An attempt was made to reveal the similarities and differences of the cities according to the analysis methods.

Keywords- AHP, DEA, Traffic Accidents, Traditional Methods, Turkey.

I. INTRODUCTION

It is predicted that 500 thousand people die and 15 million people get injured in traffic accidents worldwide every year [1]-[2]. It is known that annual cost of the traffic accidents exceeds 130 billion in the European Union and this amount is more than 1% of the Union's Gross Incomes[3]. In Turkey, more than 5 thousand people die and 200thousandpeople get injured in traffic accident every year. In other words, approximately 10 people die and more than 500 people are injured on the road everyday [4].When indirect losses in the society (disabilities occurring as a result of accidents, social and psychological pain caused by deaths or injuries) are also added to the great economic losses, which are caused by these accidents, it is obvious that no countries can be indifferent to traffic accidents.Traffic safety can be described as a dimension of the numbers of casualties and accidents generally caused by the accidents that occur within a certain time frame, mostly at times like weekend or holidays, when the traffic peaks, or a time frame such as a month/year. Traditionally, the numbers of casualties and accidents are explained with the proportional terms such as the number of casualties per kilometer traveled, per the number of registered vehicles or per population. These proportions are used to observe the trend within time. An increase in this trend generally points at a decrease in the safety, otherwise, at a development in the safety. However, these proportions cannot help us so much to examine the degree or level of the road traffic safety [5].Moreover, accident statistics, which are frequently applied, have some disadvantages such as random fluctuation, reliable recording and uniformity restriction in definitions. In addition to injury or accident data, many indicators were defined to compare the safety level and to measure the causality related to injuries or accidents or understand the processes causing accidents. Indicators that provide a more detailed view may carry the advantage of determining the problem before the results of the accidents [6]. Attempts were made to determine various road safety indicators and road safety levels with different analyses, which are applied to these indicators, in order to examine the degree or level of the road traffic safety over time. Not only the number of accidents was adhered to thanks to these studies, but also an alternative measuring and recommendation field was developed for safety [5].According to the recent studies and assessments, accidents don't have only one cause and it is quite difficult to select a cause factor which is more important than the others. But many studies and theories presented that a combination of 5 main dimensions (human, vehicle, environment, road, system) led to accidents. These dimensions are not completely independent from each other and there are many factors that influence each dimension [7].Therefore, road safety is a complicated matter affected by countless risk factors. The best way of understanding what causes an accident is the examination of the factors that lead to it [7]-[8]-[9]-[10].The factors that show influence as per the risk areas of the cities were analyzed with this study using 'Data Envelopment Analysis (DEA)' and 'Analytical Hierarchical Process (AHP)'. 81 cities of Turkey obtained scores according to their risk values and put in order in respect of these scores. Then, city orders were compared to their risk orders with the traditional method and an attempt was made to put forth the similarities and differences.

This study may pioneer the development of more efficient and sustainable policy and infrastructure projects for local and national politicians. In line with this goal and grounding on the selected variables, our primary objective is to determine the safety levels of the cities with two analyses (DEA and AHP) that are alternative to traditional methods and present the similarities and differences of the cities as per each method by putting the cities in order accordingly.

II. DATA ENVELOPMENT ANALYSIS (DEA)

Data envelopment analysis, which was developed by A.Charnes, W.W.Cooper and E. Rhodes, was used in many cases from the efficiency measurement of the police department in England to that of the banks in Cyprus and Canada and universities in America, England and France [11].
DEA is an efficiency measurement technique without parameters developed for measuring the relative efficiency of the economic decision units which resemble each other in terms of the products or services they produce [12].

Weights are internally obtained from the dataset to get the best possible score for a country/region/city in the DEA. Meaning of these weights explains what factors the performance of a country/region/city relatively depends on. This method results in weights as to the most appropriate country/region/city [13].
The possible score is determined for that country/region/city with a range of the weights obtained. Hermans et al.[14]

specified their study purpose as the determination of a direction for people making policy about the actions needed for road safety level on the basis of the DEA. Good and bad aspects of road safety were defined for every country in the model based on outputs.
They constructed a model with the DEA including road safety scores for every country taking the related road safety information for many countries into account. Shen et al.[15]
analyzed a dataset that consisted of 21 indicators for 26 European countries. They compared these 21 indicators and country performances with the DEA, which is a performance measurement technique. They presented a certain country's comparison of its relative performance with all the other countries on the basis of its self-appreciation as one of the most desirable aspects of the DEA.

III. ANALYTICAL HIERARCHICAL PROCESS (AHP)

Analytical hierarchical operation or process (AHP theory) is a method developed by Saaty in his field at the beginning of 1970s. Then, as understood, his whole objective was to convert the extensive, selected best number of alternatives into a hierarchy that was comprised of various criteria contributing to the goal. Both quantitative and qualitative criteria can be considered [16]. Decision problems are handled within a hierarchical structure and based on the logic of paired comparison. AHP finds the weights of all the criteria defined, options are evaluated again through paired comparison in terms of these criteria and then gain a weight. Paired comparison is the evaluation of which characteristic out of two is more important, how important it is, which one is preferred or dominant [17]. AHP is a comprehensible and popular technique that can be used for very complicated decisions including many levels of the criteria and subcriteria. It was used and stated as a useful means by the researchers for the assessment of indicator weights in internal environment index [18]and Index of Environmental Friendliness [19].

IV. MATERIAL AND METHOD

The topic of road safety is a very complicated field containing a high number of accident factors, humans, vehicles, environments, roads and regulations. It is a complicated topic dependent on the selection of a specific indicator (variable) group in the risk performance areas, its type, its accessibility and quality that determine the importance of each variable. Type and number of the variables depend on the countries' development level, motorization level (vehicle rate per population) and data accessibility [7].Accordingly, many variables were defined in a region/country or city representing the factors that influence the accidents. In this study, the data regarding the employment rate (%), transportation within consumption expenditures (%), alcohol within consumption expenditures (%), urbanization rate of the cities, highway networks percentage (city and state road, highway), vehicle components, population in respect of their education levels and healthy personnel (number of specialist physicians, doctors, dentists and hospital beds etc.), which belonged to 2010 and were used for 81 cities, were obtained from the Turkish Statistical Institute. Again in the study, the data about the number of accidents, red light violation, exceeding the speed limit from 10% up to 30% (512A), exceeding the speed limit by more than 30% (512B) were taken from the General Directorate Of Security (GDO) for 81 cities and the same year.81 cities of Turkey were selected for 2010 as DMU with the Data Envelopment Analysis. Economic,socio-demographic, transportation, health and education indicators of the DMUs, which were thought to represent the best regarding the main components named as road safety risk areas, were selected for each DMU (city) and activity scores were found with 18 inputs and 5 outputs, which were thought to represent these risk areas in the best way. Information about the input and output variables used in the study are presented in **Table 1**. Fixed-yield model (CRS) was used in the study in respect of the input-oriented scale [20].Again, 81 cities of Turkey were selected for the AHP and 44 factors were weighed according to their risk areas. Information about the variables/indicators that belong to the data set used in the study is presented in Table 2.

	NAME OF INPUT-VARIABLE	DATA BANK	UNIT
ECONOMIC INDICATORS			
F1	Employment participation rate	TSI	%
F2	Employment Rate	TSI	%
F3	Transportation Within Consumption Expenditures	TSI	%
F4	Alcohol Within Consumption Expenditures	TSI	%
DEMOGRAPHICAL INDICATORS			
D1	Population	TSI	Number
D2	Population density (number of people per km²)	TSI	Number
D3	Proportion of the city population within the total population	TSI	%
TRANSPORTATION INDICATORS			
T1	Component of vehicle (Cars, Minibuses, Buses, Trucks, etc.)	TSI	Number
T2	Length of road (City, Highway, village)	TSI	Km
T3	Number of cars per person	TSI	Number
T4	Red Light Violation	TSI	Number
T5	Exceeding the Speed Limit from 10% up to 30% (Including 30) (512A	GDS	Number
T6	Exceeding the Speed Limit by more than 30% (512A)	GDS	Number
T7	Other Rule Violations	GDS	Number
HEALTH INDICATORS			
S1	Number of (hospital beds, dr, Specialist dr, dentist etc.)	TSI	Number
EDUCATION INDICATORS			
E1	Number of (Illiterate,Primary school graduate, Unknown)	TSI	Number
E2	Number of (Primary education graduate, Secondary school or equivalent school graduate, High school or equivalent school graduate)	TSI	Number
E3	Number of (Academy or faculty graduate, Master graduate, PhD graduate)	TSI	Number
NAME OF OUTPUT-VARIABLE			
F5	Health Within Consumption Expenditures	TSI	%
T8	Number of Accidents	TSI	Number
T9	Number of Convicts in Prison Due to Traffic Fine 2008	TSI	Number
T 10	Traffic Risk (number of losses per 10.000 motor vehicles)	GDS-TSI	Number
T 11	Personal Risk (number of losses per 100.000 people)	GDS-TSI	Number

Table1.Input-Output Variables and Abbreviation Codes Used in the Analysis

	VARIABLE NAME	DATA BANK	UNIT
DEMOGRAPHICAL INDICATORS			
D1	Population	TSI	Number
D2	Population density (number of people per km²)	TSI	Number
D3	Proportion of the city population within the total population	TSI	%
D4	Socio-Economic Development Order of Cities-2003	GPO	Number
TRANSPORTATION INDICATORS			
TR1	Number of Cars	TSI	Number
TR2	Number of Minibuses	TSI	Number
TR3	Number of Buses	TSI	Number
TR4	Number of Pickup Trucks	TSI	Number
TR5	Number of Trucks	TSI	Number
TR6	Number of Motorcycles	TSI	Number
TR7	City and state road	TSI	Km
TR8	Highway	TSI	Km
TR9	Village road	TSI	Km
TRANSPORTATION INFRASTRUCTURE INDICATORS			
TI1	Number of Accidents	TSI	Number
TI2	Number of cars per person	TSI	Number
TI3	Number of Convicts in Prison Due to Traffic Fine 2008	TSI	Number
TI4	Red Light Violation	TSI	Number
TI5	Exceeding the Speed Limit from10% up to 30% (Including 30) (512A)	TSI	Number
TI6	Exceeding the Speed Limit by more than 30% (512A)	TSI	Number
TI7	Other Rule Violations	TSI	Number
TI8	Traffic Risk (number of losses per 10.000 motor vehicles)	TSI- GDS	Number
TI9	Personal Risk (number of losses per 100.000 people)	TSI- GDS	Number
ECONOMIC INDICATORS			
F1	GDP per Capita	TSI	Million TL
F2	Unemployment rate	TSI	%
F3	Employment participation rate (15 years and above)	TSI	%
F4	Employment Rate	TSI	%
F5	Transportation Within Consumption Expenditures	TSI	%
F6	Health Within consumption Expenditures	TSI	%
F7	Alcohol Within consumption Expenditures	TSI	%
HEALTH INDICATORS			
H1	Number of Hospital Beds	TSI	Number
H2	Number of Doctors	TSI	Number
H3	Number of Specialist Physicians	TSI	Number
H4	Number of Dentists/ /	TSI	Number
H5	Number of Pharmacists	TSI	Number
H6	Number of Nurses	TSI	Number
EDUCATION INDICATORS			

E1	(15 Years and Above) : Illiterate	TSI	Number
E2	(15 years and above) : Primary school graduate	TSI	Number
E3	(15 years and above) : Primary education graduate	TSI	Number
E4	(15 years and above) : Secondary school or equivalent school graduate	TSI	Number
E5	(15 years and above) : High school or equivalent school graduate	TSI	Number
E6	(15 years and above) : Academy or faculty graduate	TSI	Number
E7	(15 years and above) : Master graduate	TSI	Number
E8	(15 years and above) : PhD graduate	TSI	Number
E9	Educational status (15 years and above) : Unknown	TSI	Number

Table 2.Variables and Abbreviation Codes Used in the AHP Analysis

The analysis was conducted for 2010. First of all, the problem (goal) was determined in the program. It was named as road safety problem. Then, the hierarchical structure was formed. Cities were put in order from the city with the highest risk to the one with the lowest risk through the AHP, which helps us with putting them in order [20].Monitoring the number of accidents and/or casualties is generally the first preferred way to realize the traffic or safety level in a country/region or city. Traditionally, traffic or safety analyses are conducted according to the casualties order per population or vehicle-km. In this study, casualties rate per vehicle km was selected as the traditional method and it was determined for each city and an arrangement was made from the city with the highest risk towards the city with the least risk; the city orders found with the AHP and DEA were compared.

V. RESULTS AND DISCUSSION

It was preferred to use input-focused CCR model, because supervision over inputs may come into question together with the development of measures and interventions for the represented risk areas in this study. DEA determines the efficient units. However, Andersen-Petersen (AP) method was implemented for finding and putting the units, in other words, efficiency degrees in order. In Table 3, super-efficiency values of the cities are given for 2010. Six matrixes were constituted from 44 variable sets during the Analytical Hierarchical Process (AHP) (with nine rows and nine columns) and weights were given to the highest population (0.346), transportation infrastructure (0.204), and transportation (0.187), economic indicators (0.012), health (0.079) and lastly education (0.060) as a result of the AHP. City orders were set through the calculation of these weights and standardized values of each variable from 2010. In Table 3, city orders are given as per the AHP for 2010.

No	City Name	DEA Order	AHP Order	Traditional Order
1	**İstanbul**	**4**	**1**	**78**
2	**Ankara**	**6**	**2**	**60**
3	**İzmir**	**56**	**3**	**68**
4	**Bursa**	**63**	**4**	**5**
5	**Kocaeli**	**7**	6	**79**
6	Antalya	19	5	42
7	Adana	73	7	45
8	Mersin	28	8	61
9	Konya	24	9	52
10	Gaziantep	49	10	59
11	Kayseri	53	11	51
12	Denizli	46	13	50
13	Eskişehir	68	17	54
14	Samsun	58	16	63
15	Manisa	34	14	33
16	Sakarya	20	12	71
17	Aydın	31	15	55
18	Muğla	25	18	57
19	Balıkesir	70	19	47
20	Tekirdağ	43	21	70
21	Hatay	42	20	77
22	Bolu	16	26	67
23	Yalova	5	22	69
24	Diyarbakır	18	23	31
25	Edirne	15	30	74
26	Kırıkkale	32	24	80
27	Osmaniye	50	29	26
28	Trabzon	67	28	65
29	Kırklareli	30	35	19
30	Sivas	9	25	18
31	Malatya	78	37	20
32	Kahramanmaraş	29	27	56
No	**City**	**DEA**	**AHP**	**Traditional**

	Name	Order	Order	Order
33	Elazığ	80	31	11
34	Çorum	59	34	49
35	Karabük	51	32	24
36	Isparta	76	33	41
37	Bilecik	45	42	35
38	Şanlıurfa	27	38	29
39	Ordu	66	36	22
40	Zonguldak	65	41	32
41	Uşak	61	44	28
42	Düzce	39	40	76
43	Erzurum	57	39	16
44	Kütahya	71	46	27
45	Amasya	62	52	53
46	Rize	47	43	21
47	Tokat	40	51	9
48	Karaman	35	47	10
49	Burdur	75	58	34
50	Giresun	55	45	36
51	Kastamonu	77	49	17
52	Çanakkale	60	56	37
53	**Kırşehir**	**81**	**50**	**1**
54	Afyonkarahisar	41	54	39
55	Çankırı	22	55	64
56	Adıyaman	54	62	43
57	Batman	69	53	75
58	Van	74	48	46
59	Yozgat	26	57	62
60	Aksaray	64	60	30
61	Nevşehir	13	61	12
62	Erzincan	23	59	13
63	Tunceli	3	67	8
64	Artvin	48	66	38
65	Kilis	14	64	6
66	Mardin	72	71	40
67	Şırnak	8	72	72
68	Sinop	10	63	48
69	Siirt	36	73	14
70	Bingöl	17	68	15
71	Ardahan	2	79	23
72	Hakkâri	1	74	2
73	Bitlis	33	69	3
74	Gümüşhane	21	75	7
75	Ağrı	37	70	66
76	Bayburt	12	78	25
77	Bartın	11	77	73
78	Iğdır	52	76	81
79	Kars	38	80	58
80	Muş	44	81	4
81	Niğde	79	65	44

Table 3.City Orders In Reference to the DEA, AHP and Traditional Method

Instead of the traditionally-used indicators too less related to traffic safety or only such as the accident rates, city scores were formed explaining the main parameters of the road safety with variables in relation to people, vehicles and roads countrywide and covering the whole country by existing for 81 cities. Results are given in Table 3together with the orders traditionally formed with the number of losses per vehicle km. When the order results were checked, Istanbul, Ankara, Izmir, Bursa, Kocaeli, Antalya, Adana, Mersin, Konya and Gaziantep were found in the more risky city group as a result of the AHP analysis. The common point of these cities is the fact that the cities including the capital cities of Turkey - Ankara - which are economic leaders of the country were found much more risky than the eastern and southeastern cities that are way much lower than them in terms of economy, population, education and infrastructure. Problems draw attention in Hakkâri, Ardahan and Tunceli as a result of the DEA analysis. It wasn't surprising for the cities like Istanbul, Ankara and Kocaeli, which were again at the top, to appear at the top due to their dense population, mobility and motorization. Wegman et.al.[21]stated that the order obtained from different analyses wouldn't be the same on account of various reasons (for example, data quality, analysis method, random variation in the data etc.). Gitelman et al.[22] asserted that it wasn't an obligation for the analysis results they developed to be similar to the traditional order based only on death, besides, different order results would be obtained from different analyses. Hermans et al. [23] stated that the order might be influenced through the selected analysis method.

CONCLUSIONS and SUGGESTIONS

Attempts were made with this study to determine which factor of the considered city has a problem and to put the cities in order according to their risk areas without staying dependent only on the number of accidents, but also taking the other influential factors into account. For instance, the place ofIstanbul was determined as 78 in the traditional method (number of casualties/vehicle-km). How correct it is to say considering this result that Istanbul is an extremely reliable city of Turkey in terms of traffic safety or it has solved the traffic problem. However, numbers reflect a more realistic traffic problem when the other analyses are checked.

Usage of the indicator term has been increasing in recent years. Using this term is quite an important advantage to create awareness in policymakers and communication means. Propensities can be defined, problems can be predicted, policy objectives and priorities can be determined and the effect of the evaluated precautions can easily be measured together with this advantage brought by the expression convenience.

The studies show that an increase occurs in the number of accidents in parallel to the increase in the employment rate, urbanization and city and state roads. This situation resembles the developing countries where the national income per capita increases and rapid urbanization and vehicle ownership are in tendency to increase. The number of accidents decreases as the number of educated people increases. In this case, the first urgent thing to do is to make an efficient transportation plan considering the geographical and demographic characteristics of each region together with the interregional principle of equality in Turkey. It is of vital importance for every individual to try to prevent such a danger beforehand when it is supposed that everybody in Turkey and around the world has a high chance of having an accident right now.

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CONCRETE MIXTURE WITH PLASTIC AS FINE AGGREGATE REPLACEMENT

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Abstract- The objective of this research is to investigate the effectiveness of using waste plastic as fine aggregate replacement in concrete mixtures. The compressive and tensile strengths of various concrete specimens were tested to determine how the incorporation of recycled plastic as a replacement fine aggregate would affect the development of strength in the mixes. Six mixes were compared at replacement increments of 0%, 10%, 20%, 30%, 50% and 100%. All stages of plastic replacement showed a noticeable decrease in compressive strength. The 10% replacement level only showed a 15% loss of compressive strength at 28 days compared to the control. Despite being much weaker in compression, the tensile strength test showed that the 10%, 20% and 30% replacement increments were stronger in tension compared to the control. An additional test was conducted to determine whether the plastic aggregate would change the heat absorption and heat transfer of the concrete. This test showed noticeable difference between the test samples and the control. The 10%, 20% and 30% replacement mixes showed a significant decrease in heat absorption, and a minor decrease in heat transfer through the test slab.

Index Terms- Alternative recycling methods, green concrete, plastic, sustainable building materials.

I. INTRODUCTION

Concrete, one of the most common construction materials, requires a large amount of natural resources and energy. Natural resources used in concrete mixtures include lime stone, clay, sand, natural gravel, crushed stone, and water. With the rapid development in urban areas around the world in the recent years, our natural resources are depleting in an ever-increasing rate.

Therefore, it is necessary to develop a new material that consumes less natural resources and energy in order to make our construction methods more sustainable. Many efforts have been made to study the use of waste/by product materials, such as fly ash, slag, silica fume, and natural pozzolan, to replace portland cement in a concrete mixture [1-6].

Others [7-12] studied effects of plastic in concrete mixtures as aggregate replacement on material properties.While the previous studies showed potential advantages of using plastics in concrete (e.g., light weight and low energy consumption), they also reported some disadvantages, such as decreases in compressive strength and flexural strength of plastic concrete mixtures with the increase of the plastic ratio in the mixtures. Furthermore, material properties of plastic concrete mixtures may vary depending on the type of plastics that is used in the mixtures. For this reason, it was of interest of this research to study effects of one type of plastics, high-density polyethylene (HDPE), on concrete properties. This paper investigated the application of HDPE plastic on partial/full fine aggregate replacement for concrete mixtures.

II. EXPERIMENTAL PROGRAM

A. Material Preparation

Concrete materials used in this study included type I portland cement, river sand, ¾ inch crushed limestone,and water. Both sand and crushed limestone used in this study conformed to ASTM C33 [13] for concrete aggregates as fine and coarse aggregates. HDPE was selected as the plastic for fine aggregate replacement in this study. The purpose for the experiment was to determine how best to incorporate construction waste materials back into concrete saving both energy and reducing the need to discard plastic waste into landfills. The experiment began by finding the gradation of the fine aggregate owing to that the gradation of sand could provide a baseline for the desired incorporation of recycled HDPE plastic as a fine aggregate replacement option.Sieve analysis was performed on a river sand sample to determine its gradation. The gradation test was conducted in accordance with ASTM C 136 [14], and the results can be found below in Table 1. Initially, the goal was to mimic the sand gradation with the plastic gradation exactly; however, after a sieve analysis of the pulverized HDPE plastic was completed, this was deemed impracticable. As seen in Figure 1, the pulverized HDPE plastic has a much finer gradation than the sand. To accurately replace the gradation of the sand with the plastic, all of the plastic would have had to been sieved, weighted, and then remixed at the correct ratios. This process would have resulted in a lot of wasted plastic, which would have been counterproductive to the green initiative this project intended to propose.

Table 1: Sand gradation

Sieve Number	Diameter (mm)	Mass of plasticRetained (grams)	Percent Retained (%)	Percent Finer (%)
3/8"	9.53	0.0	0%	100.0%
4	4.75	13.6	0.9%	99.1%
8	2.36	89.1	5.9%	93.2%
16	1.18	183.5	12.2%	81.0%
30	0.60	419.1	27.8%	53.2%
50	0.30	641.6	42.6%	10.6%
100	0.15	155.6	10.3%	0.3%
Pan	-	3.9	0.3%	0.0%
	Sum =	1506.4		

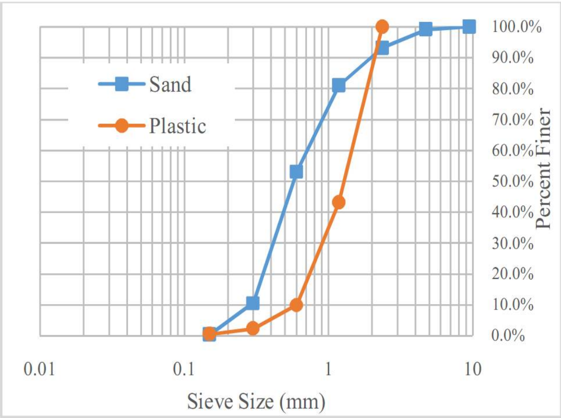

Figure 1 Gradation of sand and HDPE plastic

Further analysis of the pulverized plastic revealed that the plastic retained on the #8 sieve and larger was flat and elongated. Therefore, these sizes were disregarded, collected and re-pulverized. The increased surface area from the strips would have caused a destabilization of the concrete mixture. Also the elongated strips would have incorporated slick surfaces within the concrete, which could prevent the cement from properly adhering to the aggregate. After removing the flat and elongated pieces, another sieve analysis was performed, and the results can be found in Table 2.

Table 2: Plastic gradation from pulverization

Sieve Number	Diameter (mm)	Mass of plastic Retained (grams)	Percent Retained (%)	Percent Finer (%)
8	2.36	0.0	0.0%	100.0%
16	1.18	199.1	57.0%	43.0%
30	0.60	115.4	33.0%	10.0%
50	0.30	27.2	7.8%	2.2%
100	0.15	6.1	1.8%	0.5%
Pan	-	1.6	0.5%	0.0%
	Sum =	349.5		

In order to compensate for the removal of the #8 sieve size and above, and to model better the initial gradation of the sand, HDPE plastic pellets were added to the pulverized plastic. The quantity of pellets added was based on the original gradation of the river sand. The design gradation determined for the tests can be found in Table 3.The percent of pellets added to the plastic was based on the percent retained on the #4 and #8 sieve of the sand, i.e., the percent retained on the #4 and #8 sieve from the sand gradation (Table 1) equals the percent retained on the #8 sieve for the plastic (Table 3).

Table 3: Plastic gradation used in mix for design

Sieve Number	Diameter (mm)	Percent Retained (%)	Percent Finer (%)
4	4.75	0%	100%
8	2.36	6.8%	93.2%
16	1.18	53.1%	40.1%
30	0.60	30.8%	9.3%
50	0.30	7.3%	2.1%
100	0.15	1.6%	0.4%
Pan	-	0.4%	0%

B. Mix Design

Using the aforementioned materials, mix proportions for one control mix and five experimental mixes were created. The control mix was designed with a 0.5 water to cement ratio. The mix design was determined so that a reasonably concrete strength would be achieved to adequately determine the strength degradation induced by the increasing quantity of plastic. The experimental sample mixes utilized the same mix design with the exception of the fine aggregate. Mix designs for the control mix and the five experimental mixes with varying fine aggregate replacement levels are shown in Table 4.

The water content of the actual batch weight was adjusted to account for the absorption of the aggregates. For the HDPE plastic, due to the susceptibility of plastic to heat, an absorption testrequiring heating samples in an oven was difficult to perform. Based on the manufacturer specifications, the HDPE plastic had an absorption between 0% and 0.1%. Therefore, for the purpose of this experiment, it was assumed that the HDPE had no absorption. Recycled white HDPE plastic resin was used for the experiment to amplify the potential reflectivity of the concrete. The HDPE plastic replaced the sand by volume. As mentioned previously, both the HDPE plastic and the sand were in a state of 0% absorption. Therefore, as the volume of sand was reduced and plastic added, the water content in the sample mixes did not need to be adjusted.

Table 4: Mix proportions (kg/m^3)of the control and sample mixes

mixes

Material	Control	10%	20%	30%	50%	100%
CA (SSD)	1098	1098	1098	1098	1098	1098
FA (SSD)	829	746	663	580	414	0
Cement	307	307	307	307	307	307
Water	153	153	153	153	153	153
Plastic	0	14	27	41	68	137

C. Test Procedures

After the concrete mixtures were properly mixed, the temperature of the batch was recorded. Then the air content was determined using the pressure method in accordance with ASTM C231 [14]. Also, the slump of each concrete mix was measured according to ASTM C143 [15]. Seven 100 mm(diameter) x 200 mm (height) cylinders and one 305 mm (width) x 305 mm(length) x 25 mm(thickness) slab were produced for each mix. Cylinder specimens were made following ASTM C31 [16]. The cylinders were used for compression and tension tests, and the slab was used for testing the heat absorption of the control and experimental samples. The specimens were initially cured for twenty four hours and then placed in a water tank and cured for twenty seven days. Two cylinders were broken at seven days, fourteen days, and twenty eight days following ASTM C39 [17]. The splitting tensile strength was measured with the last cylinder. The cylinder was cut in half and the splitting tensile strength was performed on both specimens. The slabs were initially cured for twenty four hours and then removed from the molds and placed in a water tank for twenty seven days. For testing, the slabs were placed on a concrete floor. 250 watt heat lamps with reflectors were placed one foot above the slab. The lamps were run for seventy five minutes. The temperatures were measured on the front and back every fifteen minutes with an infrared heat gun.

D. Results and Discussions

Table 5provides the results of the fresh concrete tests. Due to its light weight property, the plastic aggregate caused a reduction in the unit weight of the concrete. The concrete showed a resistance to compaction, or more appropriately stated, the concrete would only remain compacted temporarily. Immediately after the concrete was rodded or vibrated the plastic acted like a spring. The plastic expanded in order to alleviate the internal stress induced by the compaction, and the expansion, in turn, created an increased air content within the concrete. Furthermore, the slump tests proved futile. Since the plastic caused expansion within the concrete, the slump test could not be considered an indicator of potential workabilityof the concrete with plastic as partial/full fine aggregate replacement. In the case of the 100% replacement sample, the slump cone grew in size, hence a negative slump valuewas recorded. Although the slump for the control and 10% replacement was very low, the actual condition for the control and 10% replacement samples wasconsidered workable. The mixes with plastic replacement levels beyond 10% showed significant loss in workability. Especially, for the 50% and 100% replacement levels, the mixesshowed lost cohesion and exhibited unworkable conditions. The measured temperatures for all samples were comparable.

Table 5: Fresh concrete properties of test specimens

Percent Replacement (%)	Slump (mm)	Temperature (°C)	Air Content (%)	Unit Weight (kg/m^3)
0	0	18	2.1	2,387
10	5	16	2.3	2,323
20	0	17	2.3	2,243
30	0	19	4.4	2,179
50	5	17	5.6	2,034
100	-5	17	10.2	1,698

Table 6 and Table 7 show the compressive strength and strength loss of test specimens, respectively. Results showed a significant variation in the strengths of the concrete samples. As the percentage of plastic replacing the sand increased, the compressive strength of the concrete decreased.At 10% replacement of the fine aggregate with HDPE, the strength of the concrete decreased by approximately 15%. Likewise, at 20% replacement, over 30% of the compressive strength of the concrete was lost. The 50% and 100% replacement samples lost cohesion and suffered from extreme loss of compressive strength. Additionally, both samples were found to be pervious. This was likely due to the unusual shape of the HDPE aggregate and the excessively high air content. The 28 day compressive strengths for the 30% plastic replacement sample turned out to be unusually weak. The reason for this anomaly was uncertain and warranted further investigation. The most likely explanation was that the cylinders broken at 28 days were poorly compacted or otherwise flawed, and these internal flaws caused the cylinders to break prematurely. It would be highly unusual for a 28-day compressive strength to be below the 7-day and 14-day compressive strengths for the same batch of concrete.

Table 6: Compressive strength of test specimens

Percent Replacement (%)	Compressive Strength		
	7-day (MPa)	14-day (MPa)	28-day (MPa)
0	26.7	37.3	41.2
10	22.9	32.5	35.2
20	18.3	24.8	28.0
30	12.1	18.2	8.1
50	6.2	9.8	9.5
100	0.8	0.9	1.1

Table 7: Compressive strength loss

Percent Replacement (%)	% Strength Loss vs. Control		
	7-day (%)	14-day (%)	28-day (%)
0	0.0	0.0	0.0
10	14.2	12.9	14.6
20	31.5	33.5	32.0
30	54.7	51.2	80.3
50	76.8	73.7	76.9
100	97.0	97.6	97.3

The split-cylinder testsshowed a different result as compared to that of the compression tests, i.e., the compression tests showed a loss of strength with the increase of plastic while the split-cylinder tests showed the opposite. As can be seen in Table 8, the control batch was weaker in tension than the 10%, 20% and 30% replacement mixes. Even the 30% replacement mix which was over 50% weaker in compression vs the control mix, was 2% stronger in splitting tensile strength. It appeared that the addition of HDPE plastic caused fundamental changes the way that concrete behaved. It was likely that the inherent stringiness of the plastic (a byproduct of the shredding/pulverizing process) provided internal shear and tensile reinforcement. The plastic behaved in a similar fashion to the way steel and synthetic fiber reinforcement fortified the concrete inhibiting the spread of cracks and fractures. Determining the optimum level of plastic replacement of the fine aggregate to attain the greatest tensile strength would require additional research and testing. The optimum amount of plastic cannot be directly interpolated because the tensile strength is dependent on two distinct variables: the compressive strength of the concrete and the amount of plastic in the mix. Additional study will be necessary to determine how each of the variables affect the tensile strength.

Table 8: Splitting tensile strength of cylindrical test specimens

Percent Replacement (%)	Splitting Tensile Strength (MPa)
0	3.15
10	3.30
20	3.70
30	3.20
50	2.80
100	0.20

There was a significant difference in the amount of heat absorbed by the concrete samples that incorporated plastic to replace the sand in the concrete mixture. Table 9 tabulates the difference in temperatures between the front and back surfaces of the concrete slab. Detailed temperature data measured during the testsare reported in Appendix. Results showed that the 10%, 20% and 30% aggregate replacement mixes absorbed heat at a slower rate as compared with the control. Furthermore, all of the sample mixes had a higher temperature differential between the front and back of the slabs compared to the control mix. The 50% and 100% replacement levels showed a much higher temperature differential compared to the other mixes, but they also absorbed much more heat than the other mixes. It is likely that at these higher replacement levels, the higher air content in the concrete inhibited the transfer of heat through the slab. Additionally, at the 50% and 100% replacement levels, the plastic was visible on the surface of the slabs. It is possible that the plastic on the surface absorbed a large percentage of the heat, preventing its ability to pass through the concrete slab.

Table 9: Temperature differentials measured from thermal conductivity tests

Percent Replacement	Temperature Differential (°C)				
(%)	15 mins	30 mins	45 mins	60 mins	75 mins
0	0.6	1.1	2.2	4.4	1.4
10	4.2	-0.8	1.7	4.4	3.9
20	5.0	1.1	5.0	10.6	4.4
30	3.9	3.3	2.8	1.9	2.2
50	8.9	6.1	7.8	7.8	5.3
100	27.5	27.8	23.1	26.9	28.3

CONCLUSIONS

The following conclusions can be drawn from this research study:

1. The temperature of the fresh concrete containing the HDPE plastic was comparable to that of the ordinary concrete.
2. The air content of the test samples increased with an increase in the percent replacement. The increase in air content was more significant when the percent replacement is greater than 30%.
3. Owing to the expansion caused by the HDPE plastic within the concrete, the slump test results could not be used as an indicator for the workability of concrete containing the HDPE plastic used in this study. For the materials used in this study, the workability of concrete decreased significantly for specimens with the plastic replacement level greater than 10%.
4. As expected, the unit weight of concrete decreased with an increase in the percent replacement owing to the light weight property of the HDPE plastic and the increase of air content due to the plastic replacement.
5. As the percent replacement increased, the compressive strength of the concrete decreased.More than 50% strength loss was observed for specimens with the percent replacementbeyond 30%.
6. The 10%, 20%, and 30% replacement samples exhibited higher splitting tensile strength than that of

the control sample. However, such increase was not observed for the specimens with percent replacement greater than or equal to 50%. The results suggested that a properpercentage of fine aggregate replaced by the HDPE plastic may be beneficial to tensile strength development.

7. The increase in the percent replacement increases the air content of the HDPE concrete, inhibiting the transfer of heat through the slab.

ACKNOWLEDGEMENT

This research is funded by the Opportunities for Undergraduate Research Experiences (OURE) program at Missouri University of Science and Technology. The authors would like to thank Conco Co. for providing the aggregates and portland cement for this research project.

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INFLUENCE OF THE FLC'S PARAMETERS OF THE UPQC IN THE DISTRIBUTED GENERATION

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Abstract- The use of Distributed Generation (DG) has been increasing in recent years to fill the gap between both energy supply and demand. This paper presents the reaction of the Fuzzy Logic Controller (FLC) when its parameters change. It is located in the DC voltage control loop of the Unified Power Quality Conditioner (UPQC) which is used to improve the power quality of the distributed generation. The main contribution of this paper concerns the impact of the different parameters of the FLC which are generally used by default in the majority of the published papers. The obtained results show that the change of these parameters affects the compensation's characteristics of the UPQC.

Index Terms- Distributed Generation, Sags voltage, Series active filter, Shunt active filter, UPQC, Wind turbine.

I. INTRODUCTION

With the augmentation of electrical energy consumption in the world- due to the process of industrialization, the electrical power generation by classical methods needs increase to fill the gap between demand and supply by using new clean generation techniques, such as, wind, solar, and micro turbines. These alternative methods are called dispersed or Distributed Generation (DG) of electrical energy. Environmental policies or concerns are probably the major driving force of the demand for distributed generation in Europe. Environmental regulations force players in the electricity market to look for cleaner- energy and cost-efficient solutions. Many of the distributed generation technologies are recognized environmentally friendly [1].

The development of power electronic technology makes it possible to realize many kinds of Flexible Alternating Current Transmission Systems devices to obtain high quality electric energy and enhance the control over power system. As result of this innovation, the implementation of Active Power Line Conditioner like Unified Power Quality Conditioner (UPQC) in DG systems to improve the power quality is gaining greater importance. The Unified Power Quality Conditioner, UPQC, is a worthwhile equipment that provides power quality compensation since it is able to mitigate power quality issues of the utility current and of the load voltage, simultaneously. In this way, many studies have been focused on improving the UPQC effectiveness and robustness, as well as ensuring its viability in high power grids [2] [3].

The main contribution of this paper concerns the impact of the different parameters of the FLC which are generally used by default in the majority of the published papers. The obtained results show that the change of these parameters affects the characteristics of compensation which are represented by the THD value.

II. DESCRIPTION OF THE SIMULATED SYSTEM

The simulation in (Fig.1) concerns a distributed generation system which contains a FACTS device called UPQC based Fuzzy Logic Controller, two passive filters which are tuned on the harmonics of rank 5 and 7 and both loads linear and non linear. The wind speed is maintained to 10 m/s. The generator is an asynchronous model. The wind energy is transformed into mechanical energy by wind turbine whose rotation is transmitted to the generator by a mechanical drive train [4].

The equations below present the modeling of the wind turbine:

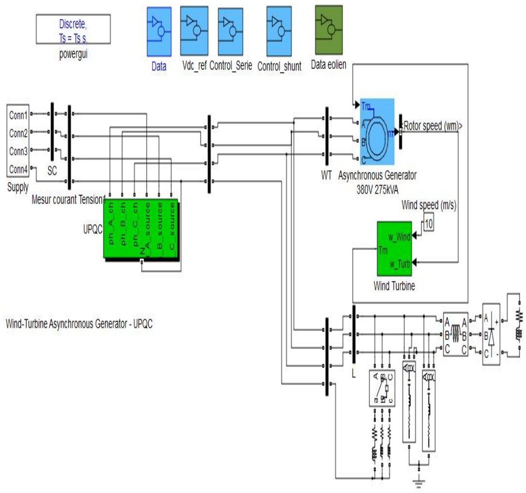

Fig. 1 The simulated system

$$P_t = \frac{1}{2}\rho \pi r^2 V^3 C_p(\lambda,\beta) \qquad (1)$$

$$C_p(\lambda,\beta) = \frac{1}{2}(\Gamma - 0.022\beta^2 - 5.6)e^{-0.17\Gamma} \qquad (2)$$

$$\lambda = \frac{w.r}{V} \qquad (3)$$

$$\Gamma = \frac{r.(3600)}{\lambda.(1609)} \quad (4)$$

where, P_t [W] is the extracted power from the wind, ρ is the air density [kg/m3], r is the turbine radius [m], V is the wind speed [m/s], β is blade pitch angle [deg], w is the rotational speed [rad/s], Cp is the turbine power coefficient which represents the power conversion efficiency and is a function of the ratio of the rotor tip-speed to the wind speed, λ is the tip speed ratio of the rotor blade tip speed to wind speed.

The torque coefficient and the turbine torque are expressed as follows [5-6]:

$$C_t = \frac{C_p.(\lambda)}{\lambda} \quad (5)$$

$$T_M = \frac{1}{2}\rho C_t(\lambda)\pi r^3 V^2 \quad (6)$$

III. UNIFIED POWER QUALITY CONDITIONER

UPQC is the integration of series and shunt active filters, connected back-to-back on the DC side, sharing a common DC capacitor. The series active filter of the UPQC mitigates the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt active filter is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance. It injects currents in the ac system so that the source currents become balanced sinusoidal and in phase with the source voltages. A basic functional block diagram of a UPQC controller is shown in Fig. 2 [7].

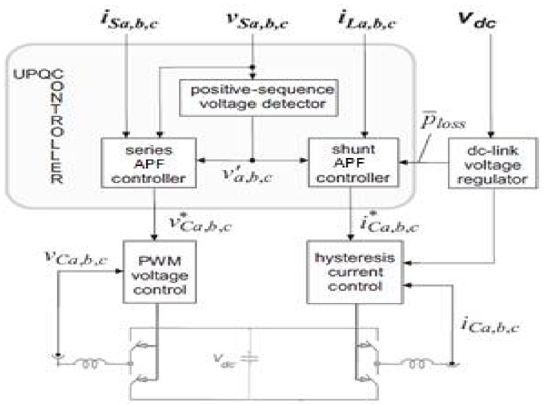

Fig. 2 Functional block diagram of a UPQC controller

A. UPQC control strategy

The control strategy can be separated to shunt strategy, series control strategy and DC capacitor control.

1. Shunt control Strategy

The shunt active filter (SHAF) is provided by the current and the reactive power (if the system needs) compensation. It acts as a controlled current generator that compensated the load current to force the source currents drained from the network to be sinusoidal, balanced and in phase with the positive-sequence system voltages.

2. Series Control Strategy

The series active filter (SAF) is provided by the voltage compensation. It generates the compensation voltage that synthesized by the converter and inserted in series with the supply voltage, to force the voltage at PCC to become sinusoidal and balanced.

3. DC Voltage controller

In compensation process, the DC side voltage will be changed because UPQC compensates the active power and the losses of switches, etc. If the DC voltage is not the same as the rating value, the output voltage of the series active filter will not equal to the compensation value. The compensation will not be correct. It is the same with the shunt active filter. The DC voltage regulator is used to generate a control signal to keep the voltage constant. It forces the shunt active filter to draw additional active current from the network. A fuzzy logic controller (FLC) converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database. Firstly, the error e (t) and the variation error Δe (t) have been placed of the angular velocity to be the input variables of the FLC. Then the output variable of the FLC is presented by the control voltage u (t). In this work, the type of fuzzy inference engine used is Mamdani type. The linguistic variables are defined as (NB, NM, NS, Z, PS, PM, PB) which mean Negative Big, Negative Medium, Negative Small, Zero, Positive Small, Positive Medium and Positive Big respectively. The fuzzy inference mechanism used in this work is given by Equation (7).

$$\mu_B(u(t)) = \max_i^m\left[\mu_{A1j}(e(t)), \mu_{A2j}(\Delta e(t)), \mu_{Bj}(u(t))\right]$$

Fuzzy output u(t) can be calculated by the centre of gravity defuzzification as:

$$u(t) = \frac{\sum_i^m \mu_B(\mu_i(t))\mu_i}{\sum_i^m \mu_B(\mu_i(t))} \quad (8)$$

Decision table (Table I) shows 49 rules of the two inputs (e and Δe) and one output (Δu). The example of the first rule is: If e is NB (Negative Big) and Δe is PB (Positive Big) then Δu is Z (Zero). The output is obtained by applying a particular rule according to the input values.

Table I
Decision table

Δu		e						
		NB	NM	NS	Z	PS	PM	PB
Δe	PB	Z	PS	PM	PB	PB	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	Z	NB	NM	NS	Z	PS	PM	PB
	NS	NB	NB	NM	NS	Z	PS	PM
	NM	NB	NB	NM	NM	NS	Z	PS
	NB	NB	NB	NB	NB	NM	NS	Z

IV. DESCRIPTION OF THE FLCS' PARAMETERS

The FIS Editor opens and displays a diagram of the fuzzy inference system with the names of each input and output variables.

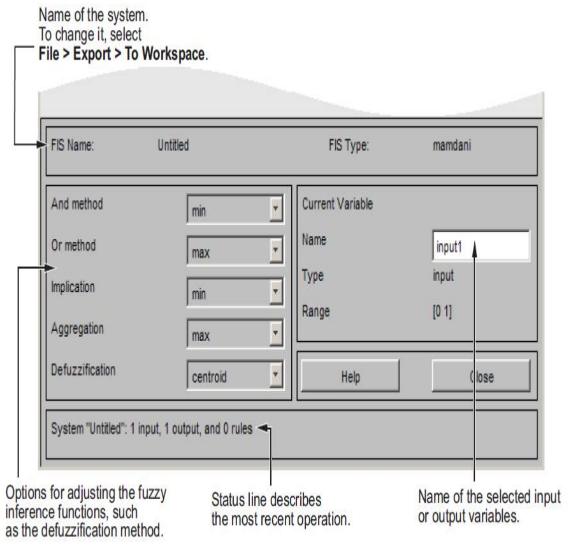

Fig. 3 FIS properties

Five pop-up menus are provided to change the functionality of the five basic steps in the fuzzy implication process:

• And method: Choose min, prod, or Custom, for a custom operation.

Min: It resolves the statement A AND B, where A and B are limited to the range (0,1), by using the function min(A,B).

Prod: It scales the output fuzzy set.

• Or method: Choose max, probor (probabilistic or), or Custom, for a custom operation.

Max: It resolves the statement A OR B, where A and B are limited to the range (0,1), by using the function max(A,B).

Probor: Probabilistic OR, y = probor(x) returns the probabilistic OR (also known as the algebraic sum) of the columns of x. if x has two rows such that x = [a; b], then y = a + b - ab. If x has only one row, then y = x.

• Implication: Choose min, prod, or Custom, for a custom operation.

• Aggregation: Choose max, sum, probor, or Custom, for a custom operation.

Sum: Simply the sum of each rule's output set.

• Defuzzification: For Mamdani-style inference, choose centroid, bisector, mom (middle of maximum), som (smallest of maximum), lom (largest of maximum), or Custom, for a custom operation.

Centroid: Centroid defuzzification returns the center of area under the curve. If you think of the area as a plate of equal density, the centroid is the point along the x axis about which this shape would balance.

Bisector: The bisector is the vertical line that will divide the region into two sub-regions of equal area. It is sometimes, but not always coincident with the centroid line.

Mom: middle of maximum (the average of the maximum value of the output set).

Som: Smallest of maximum (the smallest of the maximum value of the output set).

Lom: Largest of maximum (the largest of the maximum value of the output set).

V. SIMULATION AND DISCUSSION

FLC controller which has been chosen for evaluating the impact of its parameters is inserted in the DC voltage loop.

A. Parameters of the FLC with the unit weight

This first simulation is considered as a reference and the chosen parameters are below:

And method=min, Or method=max, Implication=min, Aggregation=max, Defuzzification=centroid, Connection=and, Weight=1

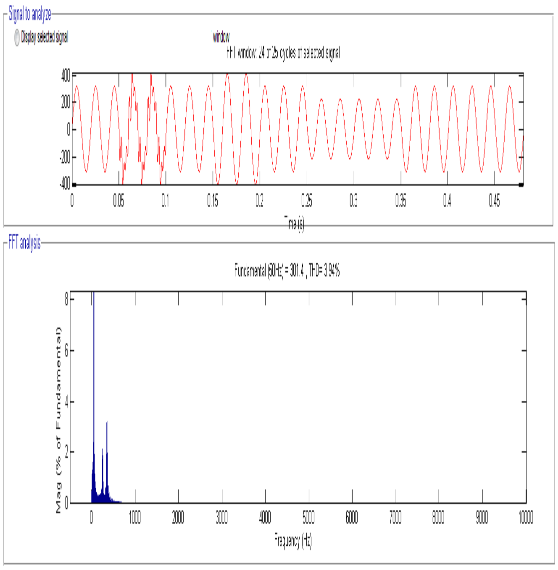

Fig. 4 Source voltage of the phase (a) and its specter

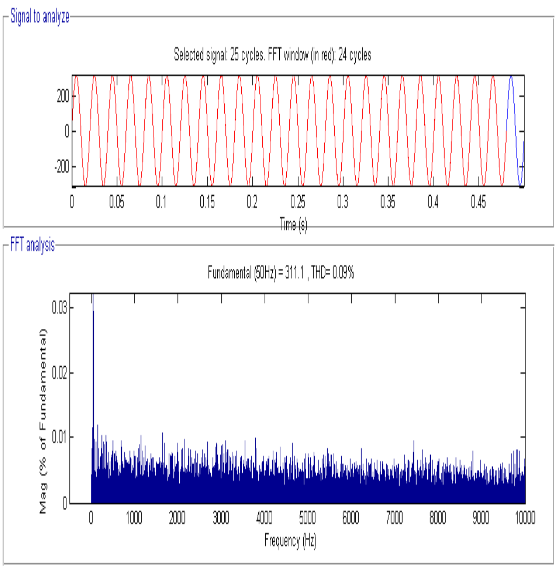

Fig. 5 Load voltage of the phase (a) and its specter

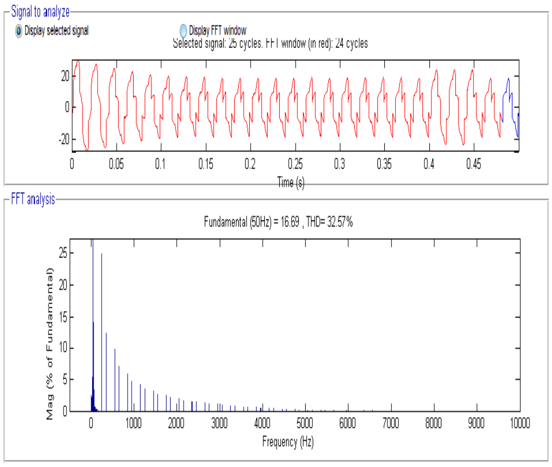

Fig. 6 Load current of the phase (a) and its specter

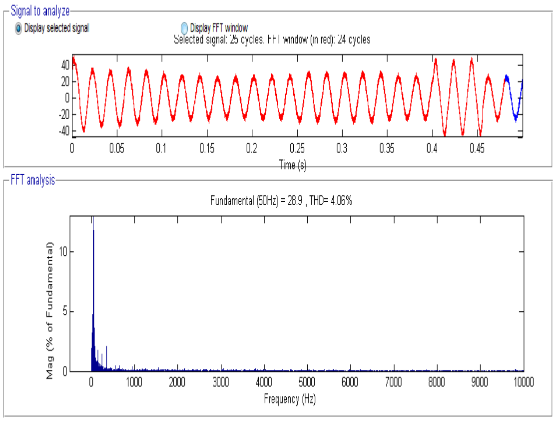

Fig. 7 Source current of the phase (a) and its specter

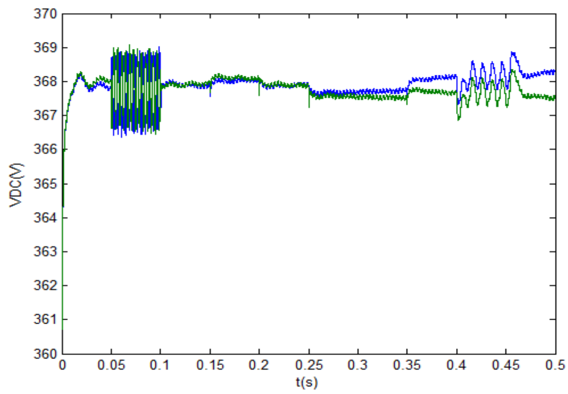

Fig. 8 DC voltage of UPQC

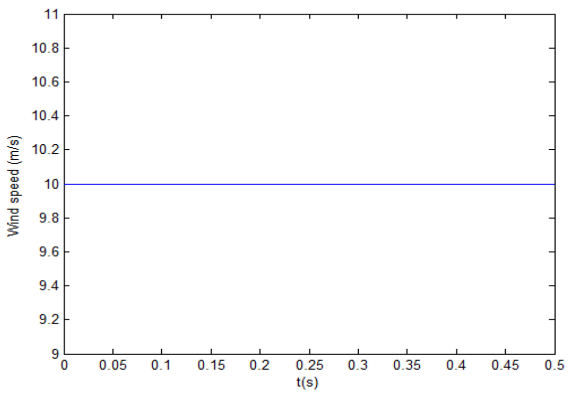

Fig. 9 Wind speed

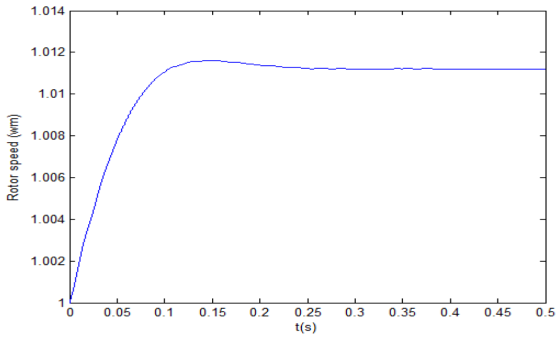

Fig. 9 Rotor speed

The source voltage (Fig. 4) has a THD value of 3.94% and contains three disturbances. The first one is caused by the harmonics 5 and 7 between 0.05 s and 0.1 s, the second represents a swell of 50% of the nominal voltage between 0.15 s and 0.2 s, and the last one is sags voltage of 50% between 0.3 s and 0.35 s. After compensation (Fig. 4), the load voltage is kept at nominal value with a THD value equal to 0.09%. The THD value of the non linear load (Fig. 6) is equal to 32.57%. The source current (Fig. 7) has become sinusoidal with a THD value of 4.06%. Each part of the split capacitor follows its reference voltage (Fig. 8). The impact of the voltage harmonics of the supply voltage is noticeable on the DC voltage between 0.05 s and 0.1 s but without significant impact on the load voltage. The wind speed (Fig. 9) is maintained constant at 10 m/s and the rotor speed too (Fig. 10), due to the control circuit.

B. Parameters of the FLC with the variable weight

And method=min, Or method=max, Implication=min
Aggregation=max, Defuzzification=centroid,
Connection=and, Weight= variable from 0.1to 1

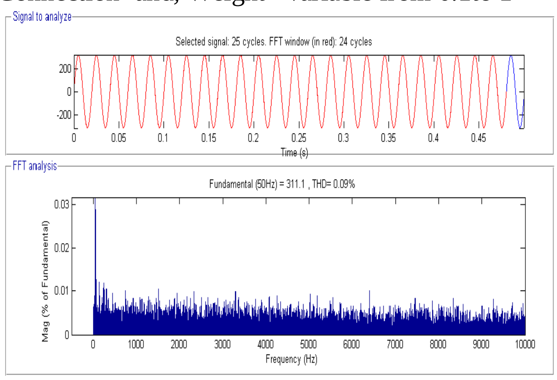

Fig. 11 Load voltage of the phase (a) and its specter

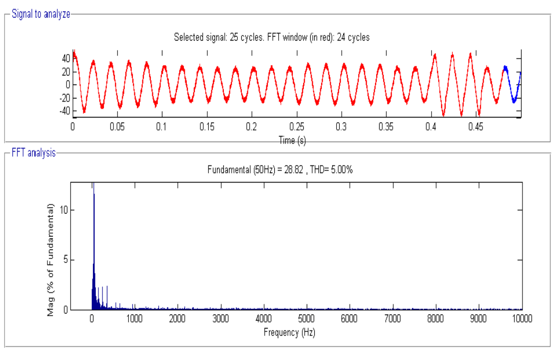

Fig. 12 Source current of the phase (a) and its specter

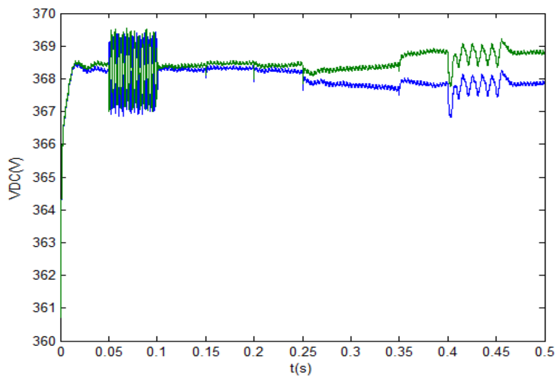

Fig. 13 DC voltage of UPQC

In this case, we have changed the weight value for evaluating its impact during the inference. Generally, the user of the membership fuzzy editor (mfedit) of MATLAB/SIMULINK uses the default value which is equal to 1. The supply and the load are kept at the same conditions as the first simulation. The load voltage (Fig. 11) remains without change with the same value of the THD. Otherwise, we have noticed that the THD value of the source current (Fig. 12) has endured a small change and is equal to 5%. Also, the DC voltage response (Fig. 13) shows a small divergence at the end but without significant influence on the THD value.

C. Parameters of the FLC with new functions

And method=prob, Or method=probor, Implication=min

Aggregation=probor, Defuzzification=som

Connection=and, Weight=1

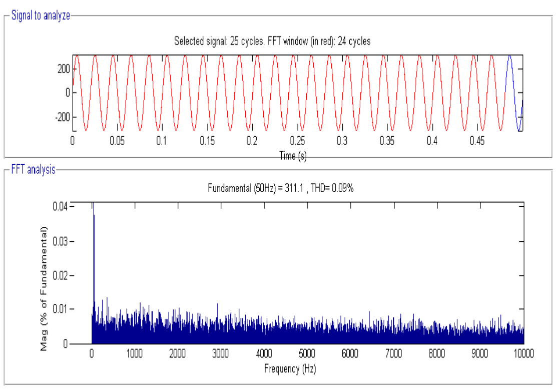

Fig. 13 Load voltage of the phase (a) and its specter

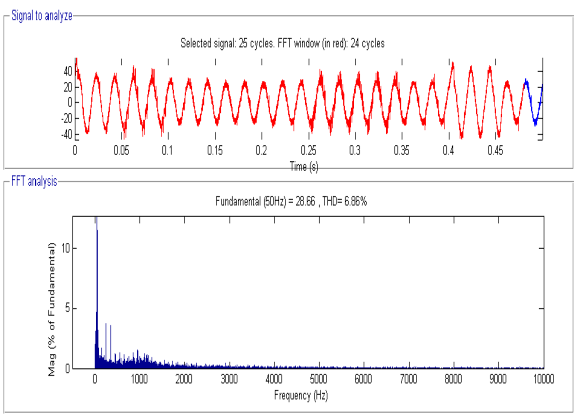

Fig. 15 Load voltage of the phase (a) and its specter

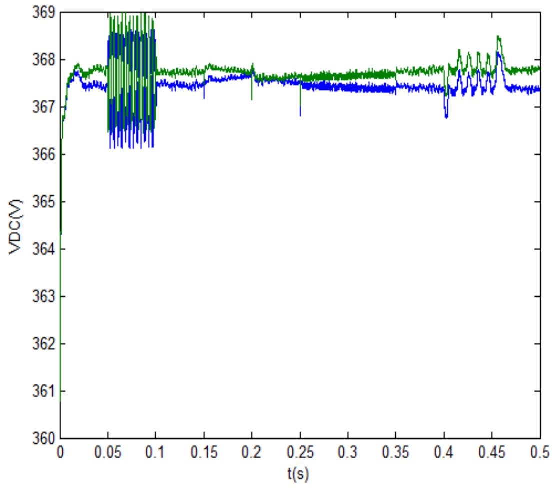

Fig. 16 DC voltage of UPQC

For this last simulation, we have changed the FLC's FIS properties of the DC voltage loop. All characteristics (Figs 14-16) are remained unchanged. The THD value of the source current has endured a small increase.

CONCLUSION

The FLC has become a solution when the classical controller does not satisfy the performance's criteria. Especially, when the non linearity of the model is more important but, the most users of this kind of control use the default parameters of the FIS proprieties. In this paper, we have presented the different functions which are contained in the membership fuzzy editor and also, we have used them for evaluating their impact on the behavior of the FLC which is inserted in the DC voltage loop of the UPQC. The obtained results show that the best choice of these parameters could be a way to improve the system's response such as the variation of the membership function's number or the different functions of the defuzzification. The obtained results in different cases have shown a small change of the behavior of the FLC.

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IMPACT OF PLANT HEIGHT AND IRRIGATION ON THERMAL PERFORMANCE OF EXTENSIVE GREEN ROOFS IN RIYADH CITY

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Abstract- Increasing worldwide environmental concerns (Global warming, depletion of natural resources, acidrains, air and water pollutions, and ozone depletions) have led to the development of environmentally friendly construction practices. Green roof is one of the sustainable practices for reducing the environmental impact of a building. The study aim was identifying the impact of plant height and irrigation on thermal performance of an extensive green roof system in Riyadh city influenced by tropical and harsh climate.The experimental validations were applied on residential building in Riyadh city during the summer season in 2014. The experimental validations results indicated that the tall grass with average height from 6 to 15cm can reduce the temperature of internal air from 0.5 to 1°C, in comparison to the short grass with average height from 3 to 6 cm in similar conditions. While, the temperature of internal air differences were of 0.0±0.5°C with regular irrigation or irregular irrigation. However, when irrigation stopped more than two days, the grass would wither. Finally, this study has demonstrated that the grass height was more effective for its impact on the thermal performance than regular or irregular irrigation.

Keywords- Internal Temperatures,Irrigation,ShortGrass, Tall Grass, Thermal Performance.

I. INTRODUCTION

Green canopy have an important role for roof cooling, which is depending on plant species in terms of shading, evapotranspiration, and irrigation which acts as an insulator. The experimental results of [3]confirm that the plant canopy reflects 13% of incident global solar radiation and absorbs 56%, so that the solar radiation entering the system can be then estimated as 31% of the incident global solar radiation. The thermal behavior of a green roof is a complex phenomenon (such as shading, evapotranspiration, conductivity and absorption) and involves combined heat and mass transfer exchanges. Various studies have analyzed the thermal performance of green roofs in different plant varieties. According to [5]–[2], different plants have different results at the levels of effectiveness. As the amount of the coverage increased, the magnitude of the temperature changed (decreased). Because of this, the parametric variations in leaf area index (LAI) and foliage height thickness are carried out to determine the modulation of canopy air temperature, the reduction in the temperature width, and to estimate the penetrating heat flux. Also, foliage acts as a shading device under which convection provokes heat thermal exchange, but foliage absorbs part of the thermal energy because of its vital process of photosynthesis.
Furthermore, the results being drawn from the study of [8]showed that the effects of temperature reduction decrease with plant height. The best reductions in temperature occurred in 35 cm plants, followed by 15 cm and then 10 cm plants. The results also indicate that plants with green colored leaves are more effective than purple/red leafed plants in rooftop heat insulation. The leaf surface temperatures in this study were measured with infrared thermal imagers. However, the study of [15] found out that the most important parameter, when considering vegetation, is the foliage density. The foliage height alone is not one of the crucial factors affecting the performance of this cooling technique, but only in combination with the density of the vegetation layer. Moreover, the study of [1]found out that a larger leaf area index(LAI) reduces the solar flux penetration, stabilizes the fluctuating values, and reduces the indoor air temperature. Also, the study showed notably that in terms of evapotranspiration (ET) and solar heat gains factor (SHF), the foliage density and hence the vegetable canopy type selection influence the thermal efficiency of the climatic insulation greatly. In addition, the study of [10]compared the thermal effectiveness among three kinds of plant (Sedum, Plectranthus, and Kalanchoe) on an extensive green roof in an Indian Ocean area under a tropical humid climate. The results showed that Sedum green roof led to a higher heat restitution rate with 63%, than for Plectranthus (54%), and Kalanchoe (51%). In general, the results drawn from the study of [11] showed that a green roof which has high vegetation density acts as a passive cooling system. The incoming thermal gain is about 60% lower than when the roof has no vegetation. Irrigation is required to sustain vegetation throughout the extended dry periods. The water requirements of the plant species is from 2.6 to 9.0 L/m2per day, depending on the plant kind and the surrounding conditions [14]. Moreover, the study of [7]compared the irrigation among four plant types (C. chinense, C. variegatum, S. trifasciata, and cv. Laurentii). The study indicated that if plant leaves have greater evapotranspiration rates, they would not adapt to arid and severe environments for longer periods, thereby increasing water consumption. In contrary, plants with low evapotranspiration rates are suitable for arid and severe environments, thereby saving water resources. In addition, the study of [13]provided experimental evidence for a positive effect of the water retention

layer on water status and drought survival of plants growing over green roofs. The water retention layer is better than the natural sand and soil for increasing the amount of water available in green roof systems. Therefore, some studies investigated the irrigation impact on the thermal performance of the extensive green roofs. According to [12]–[2]the presence and the quantity of water largely influence the thermal properties of green roofs. In fact, a wet roof provides additional evapotranspiration, which prevents the heat flux in buildings and acts as a passive cooler by removing heat from buildings. Also, the study of [4]found out that the difference between the soil surface temperature of a dry substrate and a saturated substrate is about 25 °C. In conclusion, the study of [9]found out that supplemental irrigation is required for maintaining plant diversity on an extensive green roof, but not necessarily plant cover or biomass which depends on the growing media type being used. Also, the results showed that planting extensive green roofs with a mix of plant species can ensure the survival of some species; maintaining cover and biomass when supplemental irrigation is turned off to conserve water, or during extreme drought.

II. METHODOLOGY

The method being adopted in this research depends on the mixed scanning approach which involves reviewing the research problem in the literature and compare the theoretical findings with the experimental validations in order to identify the impact of plant height and irrigation on the thermal performance of the extensive green roof in Riyadh city.

2.1 Application study

In order to obtain an experimental data regarding the thermal behavior of extensive green roofs and their interactions with the energy performance of buildings, an experimental platform with green roofs system was constructed in the Deraib region which is located in the north of Riyadh city. The experimental platform is a simple repetition of residential rooms being built by similar materials. The platform consists of two rooms which are used for the study of treatment of the energy efficiency of buildings by using a selective standard for extensive green roof properties, and conventional roofs (concrete roof with depth of 15cm), see Figure (1). Also, the facades of these rooms will be painted with the Paige color, see Figure (2). To reflect a real urban setting, the experiment was conducted on the residential building that could simulate both physical and geometrical similarities in reality. The application study consists of three stages: the stage of experiment preparation, the stage of data collection, and the stage of data analysis and discussion.

2.2 Heat measurement equipment

The normality of temperature and the relative humidity data was checked by using (The EL-USB-2-LCD+) which measured the air temperature and the relative humidity inside the rooms and outside the rooms every five minutes. Thermocouples sensors (ANRITSU Digital handheld thermometer - ANRITSU MTER CO.,LTD) were arranged in different levels within the model to include the components of the empirical model so as to measure the covariance of temperature. Heat flux sensors were placed on the surface of the plants, walls, and at the ceiling layer in order to assess the amount of the heat conduction of those components. The results of the experiment were analyzed by using the statistical analysis program of Microsoft Excel.

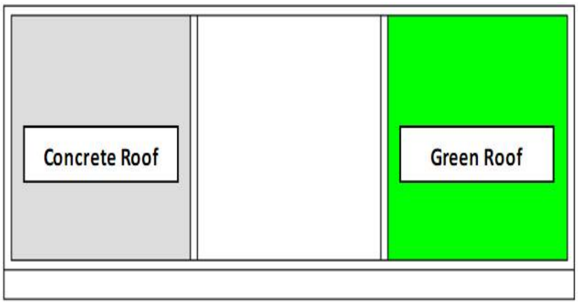

Figure: (1) The Plan's view of the experimental program.

Figure: (2) shows the exterior finishes in test rooms.

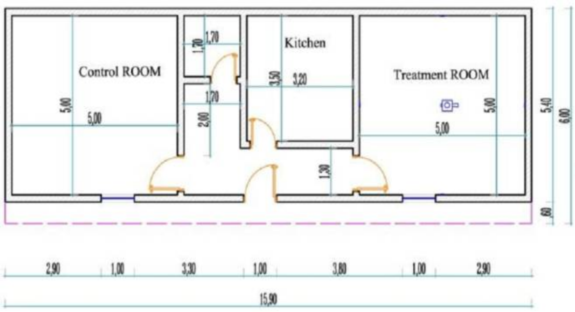

Figure: (3) A Plan's view of the rooms being tested.

A Pre-cultivated system (Vegetative Blanket - Tifway 419 Bermuda) was used in this experiment. This type typically comes in rolled that can be placed on any roof and be grown off-site. Also, this type has a good advantage ; namely, it is very thin (very lightweight option) compared to the other types.

An extensive green roof system consists of following matter Figure (4):

- A5 mm thick styrene butadiene rubber (SBR) waterproofing membrane (preventing water from reaching the roof decking in an actual field installation).

- A 0.1 mm thick polyethylene slip sheet allowed any moisture in the waterproofing membrane to exit the system and saving water for irrigation.
- A 3 cm thick gravels which is as drainage layer and saving soil from erosion.
- A 2 cm thick sand that acts as a filter layer for drainage.
- A 4 cm thick soil which consists of mixed ratio (1:1:3) –(batamos: clay soil: soft sand) with organic materials.
- A 3 cm thick vegetative roll layer with Cynodondactylon (Bermuda- Tifway - 419) grass.

Drainage pipes of excess water from the growing medium were channeled and installed in the corners of the green roof substrate to allow water to drain freely from the system.

2.3 Installation of Measuring devices

There are 24 sensors that are used in this test. Eight sensors are in the green roof system, see Figure (5), two sensors are in the concrete roof system, six sensors are in the treatment room walls, six sensors control room and two sensor out test rooms.

III. DATA COLLECTION AND ANALYSIS

Thermal performance of extensive green roofs was during the warm period. The warm period chosen for the analysis was in June 2014 from (06-June to 23-June), which is a representative of a typical summer season in Riyadh city. The daytime is characterized by high loads of solar radiation with an average air temperature of 42◦C and an average relative humidity of 15.1%. Days presented winds with daily average and max value from 4.0 km/h to17.0 km/h.

3.1 Grass Height

A Tall Grass

Figure (6) shows the high of grass during the time period test. The height was from 8cm to 15cm. Figure (7) shows that the average values of the internal air temperature differences were of 5.5±2°C among the treatment and control rooms with tall grass, when the external air temperature reached to 44°C.

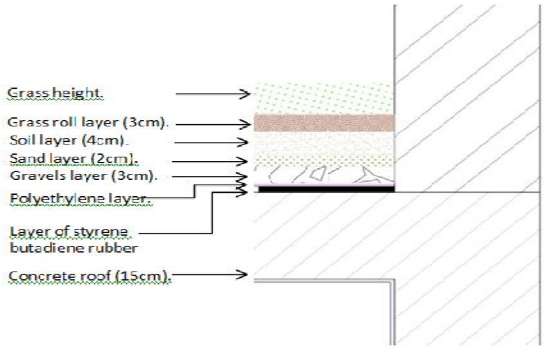

Figure: (4) The vertical section shows the various components of the extensive green roofing system

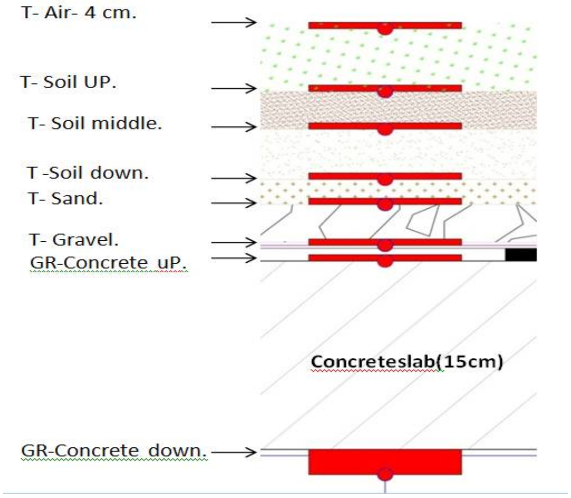

Figure: (5) The vertical section shows the sensors' places in the extensive green roof system.

Figure: (6) Shows the growth of the tall grass of (8-15) cm during the testing period.

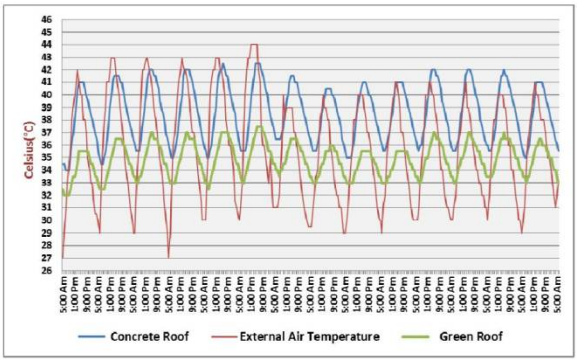

Figure: (7) Temperature variation of the internal air temperature in treatment room and control room with tall grass during the time period from 6-6-2014 at 5:Am to 20-6-2014 at 5:Am.

Figure (8) shows the temperature of thermocouples in substrate layer of extensive green roof system. The average values of substrate layers temperature differences were of 1±.01°C during the testing time period. The maximum temperature of substrate layers reached to 50°C when the external air temperature was 43°C and the minimum temperature of substrate layers reached to 34°C when the external air temperature was 28°C. However, the internal ceiling temperature was lower than the top layer of substrate (grass layer) up from 4°C to 14°C. While the air temperature at 4cm in the grass layer reached 58°C because of the evapotranspiration phenomenon. Also, Figure (8) shows that the performance of substrate layers were different during the time period of day. During the night period, the lower layers of temperature were lower than the uppers layers of temperature. While during daylight period, the lower layers of temperature were higher than the uppers layers of temperature.

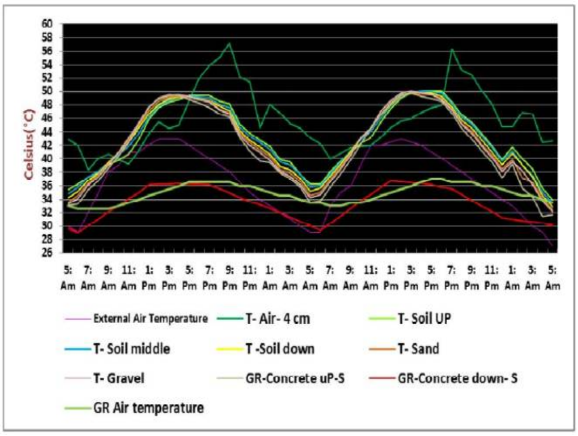

Figure: (8) Temperature variation of substrate layers with tall grass (regular irrigation) during the time period from 7-6-2014 at 5: Am to 9-6-2014 at 5:Am.

B Short Grass

Figures (9 and 10) show the method of cutting grass to test the impact of grass height on the thermal performance of the extensive green roof system. The grass height after cutting was from 3cm to 5cm.

Figure: (9) Shows the method of cutting grass.

Figure: (10) Shows short grass on 20-6-2014.

Figure (11) shows that the average values of the internal air temperature differences were of 5.5±2.5°C for the extensive green roof system (with short grass) being compared to the concrete roof system, when the maximum external air temperature reached 42°C and the minimum external air temperature reached 29°C. Also, Figure (12) shows the temperature of thermocouples in the substrate layer of the extensive green roof system after cutting grass with 5cm height. The average values layers temperature differences were of 2.5±.01°C during the daylight. The maximum temperature of substrate layers reached to 51°C when the temperature of external air was 41°C. However, the temperature of internal ceiling was lower than the top layer of the substrate (grass layer) from 7°C to 13°C during the daylight.

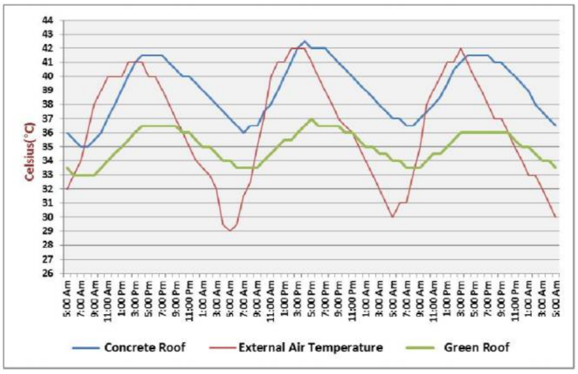

Figure: (11) Temperature variation of the internal air temperature in test rooms with short grassduring the time period from 20-6-2014 at 5:Am to 23-6-2014 at 5:Am.

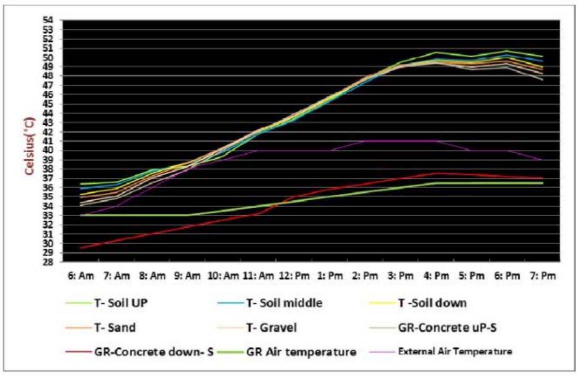

Figure: (12) Temperature variation of substrate layers with short grass (regular irrigation) during the time period from 20-6-2014 at 6:Am to 20-6-2014 at 7:Pm.

3.2 Irrigation

Irrigation was required to sustain vegetation throughout the extended dry periods. The water requirements of the plant species in this experiment were 6.0 L/m2 per day. The manual irrigation method was used at 6:30 pm every day for five to six minutes, see Figure (13).

Figure: (13) The method of manual irrigation during the testing period.

A The impact of irrigation on the temperature of internal air As shown in Figure (14), the temperature of internal air in the treatment room (with regular irrigation) was lower than the temperature of internal air in the same room (without irrigation for one day to two days). The differences were of 0.5°C during the testing period. This means that the higher the water volumetric content, the lower the minimum of the daily temperature.

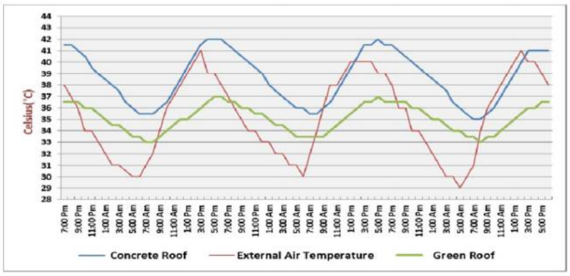

Figure: (14) Temperature variation of the internal air temperature in treatment room and control room with tall grass (first day irrigation, next day off and third day off too) during the time period from 160-6-2014 at 7:Pm to 19-6-2014 at 5:Pm.

B The impact of irrigation on the performance of substrate layers

Figure (15) shows the impact of regular and irregular irrigation on the temperature of substrate layers in the extensive green roof system with tall grass through the thermocouples sensors. When the temperature of external air was 40°C, the average values layers of the temperature differences were of 2.5±.5°C during the daytime. When regular irrigation, the maximum temperature of substrate layers reached 49°C, while with irregular irrigation (day off) the maximum temperature of substrate layers reached 51.4°C .

In addition, While the air temperature at 4cm in the grass layer reached 57.8°C on the day of regular irrigation. It reached 49.5°C on the day with irregular irrigation (day off) because of the evapotranspiration phenomenon. Before the irrigation, the soil temperature of the layer surface reached 49°C, while the water was cold. So, the water evaporated and the air temperature increased.

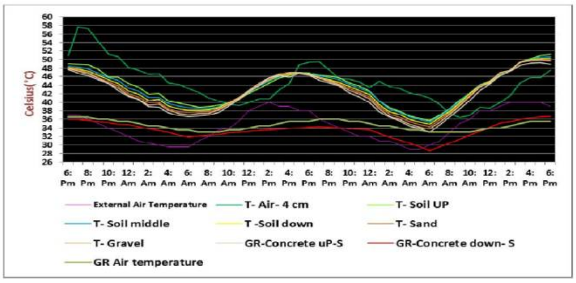

Figure: (15) Temperature variation of substrate layers temperature in extensive green roof system with tall grass (first day irrigation and the second day off) during the time period from 12-6-2014 at 6: Pm to 14-6-2014 at 6:Pm.

IV. DISCUSSIONS

The discussion focused on the impact of substrate components (grass height and water content) and the temperature of internal walls on the thermal performance of the extensive green roof system. The discussion includes the temperature variation of the internal air, Substrate layers, and internal (Globe) temperature.

4.1 Grass Height

The tall grass with average height from 6 to 15cm can reduce the temperature of internal air from 0.5 to 1°C, in comparison to the short grass with average height from 3 to 6 cm in similar conditions, as it is shown in Table (1). In the treatment room with tall grass, the temperature of internal airvaried from 35.5 to 33°C. But in the treatment room with short grass, the temperature of internal air varied from 36.5 to 33.5°C. This means that the leaf area and the foliage height thickness could reduce penetrating heat flux by shading and evapotranspiration phenomenon.

Moreover, the grass height has a significant impact on the temperature of the substrate layer. As shown in Table (2), the temperature of substrate layers varied from 50 to 32°C with tall grass, while the temperature of substrate layers varied from 51 to 33°C the maximum temperature of the external air were 43°C and 41°C respectively during the daylight. So, the tall grass temperature of substrate layers was lower than that of the short grass during similar conditions. However, the temperature of beneath layer in the substrate (Gravels layer) was lower than the top layer in the substrate (soil layer) during the first morning hours. But at noon, the gravel layer temperature was higher than the soil layer, due to the increasing of the thermal storage.

Celsius	Internal Air Temperature			
	Time period from 15-6-2014 at 5: Am to 16-6-2014 at 5:Am.		Time period from 20-6-2014 at 5: Am to 21-6-2014 at 5:Am.	
	External Air Temperature	Treatment Room (Green Roof) Tall Grass	ExternalAir Temperature	Treatment Room (Green Roof) Short Grass
Maximum	41°C	35.5°C	41°C	36.5 °C
Minimum	29°C	33°C	30°C	33.5°C
Difference	12°C	2.5°C	11°C	3°C

Table: (1) Temperature variation of the internal air temperature in treatment room with tall grass and with short grass.

Celsius	Substrate layers Temperature Variation			
	Time period from 7-6-2014 at 6: Am to 7-6-2014 at 7: Pm.		Time period from 20-6-2014 at 6: Am to 20-6-2014 at 7: Pm.	
	External Air Temperature	Treatment Room (Green Roof) Tall Grass	ExternalAir Temperature	Treatment Room (Green Roof) Short Grass
Maximum	43°C	50°C	41 °C	51 °C
Minimum	30°C	32°C	33°C	33°C
Difference	13°C	18°C	8°C	18°C

Table: (2) Temperature variation of substrate layers temperature with tall grass and with short grass.

4.2 Irrigation

As shown in Table (3), the regular irrigation or irregular irrigation in the extensive green roof system did not have a significant impact on the thermal behavior of the extensive green roof system. The temperature of internal air in the treatment room with regular irrigation varied from 36.5 to 33.5°C during the daylight, while it varied from 37 to 33.5°C in the treatment room with irregular irrigation when the external air temperature varied from 40 to 31°C and from 40 to 30°C, respectively. The temperature of internal air with regular irrigation was lower than that with irregular irrigation. The temperature differences were of 0.0±0.5°C. However, when irrigation stopped more than two days, the grass would wither. In addition, as shown in Table (4), the temperature of substrate layers varied from 49 to 33.6°C with regular irrigation, while the temperature of substrate layers with irregular irrigation varied from 51.4 to 33°C when the external air temperature varied from 40 to 30°C during the daylight. The substrate layers temperature differences were of 2.4±0.6°C with regular or irregular irrigation. From these results and through the comparison of the impact of grass height and irrigation on the thermal performance of extensive green roof, the grass height was more effective for its impact on the thermal performance than regular or irregular irrigation.

Celsius	Internal Air Temperature			
	Time period from 12-6-2014 at 5: Am to 12-6-2014 at 5: Pm.		Time period from 18-6-2014 at 5: Am to 18-6-2014 at 5: Pm.	
	External Air Temperature	Treatment Room (Green Roof) regular irrigation	ExternalAir Temperature	Treatment Room (Green Roof) Irregular irrigation
Maximum	40°C	36.5°C	40°C	37°C
Minimum	31°C	33.5°C	30°C	33.5°C
Difference	9°C	3°C	10°C	2.5°C

Table: (3) Temperature variation of substrate layers temperature with regular and irregular irrigation.

Celsius	Substrate layers Temperature Variation			
	Time period from 13-6-2014 at 5: Am to 13-6-2014 at 7: Pm.		Time period from 14-6-2014 at 5: Am to 14-6-2014 at 7: Pm.	
	External Air Temperature	Treatment Room (Green Roof) regular irrigation	ExternalAir Temperature	Treatment Room (Green Roof) Irregular irrigation
Maximum	40°C	49°C	40°C	51.4°C
Minimum	29°C	33.6°C	29°C	33°C
Difference	11°C	16°C	11°C	18°C

Table: (4) Temperature variation of the internal air temperature in treatment room with regular and irregular irrigation.

CONCLUSION

A number of conclusions can be drawn from the experimental study presented and
discussed in this study. The conclusions are the main results of this study.

The results of this study indicate that:

- Tall grass (6 to 15) cm was better than short grass (3 to 5) cm for reducing the temperature of internal air from 0.5 to 1°C.
- Tall grass (6 to 15) cm has a significant impact on the temperature of the substrate layer during the daylight in comparison with short grass (3 to 5). The temperature variation reached 3.8°C.
- The regular irrigation or irregular irrigation in the extensive green roof system did not have a significant impact on the thermal behavior of the extensive green roof system, especially for internal air temperature. The maximum temperature variation was up to 0.5°C. However, when irrigation stopped more than two days, the grass would wither.
- Water content with regular irrigation could cool the temperature of substrate layers more than irregular irrigation. The substrate layers temperature differences were of 2.4±0.6°C with regular or irregular irrigation.
- The temperature of internal walls in the treatment room (Green Roof) was higher than that in the control room (Concrete Room). However, the temperature of internal air in the treatment room was lower than that in the control room due to the use of the extensive green roof system. The temperature differences of internal air were of 5.5±2°C.
- Due to the increase of the thermal storage, the temperature of the beneath layer in the substrate (Gravels layer) was lower than the top layer in the substrate (soil layer) during the first morning hours, while at noon the gravel layer temperature was higher than the soil layer.

ACKNOWLEDGMENTS

This project was supported by the Research Center of Architecture and Planning College, King Saud university, Kingdom of Saudi Arabia.

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AN ANALYSIS OF MOBILE BANKING CUSTOMERS FOR A BANK STRATEGY AND POLICY PLANNING

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Abstract-Online banking is increasingly common. Financial institutions deliver online services via various electronic channels, subsequently diminishing the importance of conventional branch networks. This study proposed an integrated data mining and customer behavior scoring model to manage existing mobile banking users in an Iranian bank. This segmentation model was developed to identify groups of customers based on transaction history, recency, frequency, monetary background. It classified mobile banking users into six groups. This study demonstrated that identifying customers by a behavioral scoring facilitates marketing strategy assignment. Then the bank can develop its marketing actions.Thus, the bank can attract more customers, maintain its customers, and keep high customers' satisfaction.

Keywords- Data mining;mobile data, mobile banking; customer segmentation

I. INTRODUCTION

The newly emerging channels of online banking and rapidly increasing penetration rates of mobile phones motivate this study(C. S. Chen, 2013).

The internet has had a significant impact on financial institutions, allowing consumers to access many bank facilities 24 hours a day, while allowing banks to significantly cut their costs. Research has shown that online banking is the cheapest delivery channel for many banking services (Koenig-Lewis, Palmer, & Moll, 2010; Robinson, 2000). A number of studies have identified advantages to bank customers, including cost and time savings as well as spatial independence benefits (Koenig-Lewis et al., 2010).

According to Gartner's prediction of leading trends of 2012 in mobile applications, mobile commerce (m-commerce) remains the most important one. Gartner further forecasts that mobile devices will replace PCs as the main device to access the internet. As for the third quarter of 2012, IPSOS indicated that "The era of Multi-Screen has come, and smartphones account for the purchasing behavior of 65% of mobile device users." According to that report, 66 percent of the smartphone holders in Taiwan access the internet via a smartphone at least once daily; approximately 57 percent of the customers perform mobile searches; and 40 percent of the customers shop via mobile phones(IPSOS, 2012). These statistics reflect vigorous growth in the scale of m-commerce. However, mobile banking remains in its infancy, and international adoption rates demonstrate the strong potential of m-commerce(FRB, 2012). Therefore, data mining for mobile banking is of priority concern for further developing mobile banking services (MBSs) (C. S. Chen, 2013).

Moreover, recent developments in Internet connectivity have led to a renewed interest in Internet banking among specific groups of working individuals. Moreover, with the rapid development of mobile and smart phones, Internet banking has become more conducive to many more individuals, since they can carry out their banking transactions anywhere and anytime (Govender & Sihlali, 2014; Lee & Chung, 2009). Mobilebanking, an extension of Internet banking, provides time independence, convenience, prompt response to customers and cost savings. These benefits serve as an opportunity for banks to increase consumer market through mobile services. Furthermore, mobile technologies, such as smart phones, PDAs, cell phones, and iPads have not only become ubiquitous, but also trendy among young adults(Govender & Sihlali, 2014).

Moreover, in recent years the market orientation has changed to customer centric view. After realizing the importance of simultaneous use of various channels, banking and financial companies are now paying attention to mobile banking especially when it comes to maintenance of customer relationships (Sangle & Awasthi, 2011). The ability to identify customer's most pressing need at a given moment of time is one of the promising propositions of mobile banking. Advanced mobile technologies help banks in offering new services like viewing account details, fund transfer, balance enquiry, loan details, bill payments, enquiry about credit card and demat account and add value to existing ones by disseminating the information at userdefined time and place(Sangle & Awasthi, 2011).

Besides, banking was at the forefront of the service sectors that migrate customers from face-to-face transactions to computer-mediated transactions. With the development of m-commerce, similar expectations have been held out that much banking activity that is currently carried out online through fixed line internet terminals will migrate to mobile devices. The range of services that can be undertaken while mobile is likely to increase, and mobile phones are likely to evolve as ubiquitous payment devices(Koenig-Lewis et al., 2010; Wilcox, 2009).

Market segmentation is one of the most important areas of knowledge-based marketing. In banks, it is really a challenging task, as data bases are large and multidimensional(Zakrzewska & Murlewski, 2005).

Though a number of aspects have been studied for m-commerce, very little is reported regarding the customer segmentation of mobile banking from customer relationship management (CRM)perspective(Wong & Hsu, 2008). The knowledge of the key mobile user segments in financial sector is still lacking. This study attempts to add to the body ofliterature by data mining in mobile banking services(Sangle & Awasthi, 2011).

In relation to customer-centric business intelligence, banks are usually concerned with the following commonMarketing and sales concerns(D. Chen, Sain, & Guo, 2012):

- Who are the most / least valuable customers to the bank? What are the distinct characteristics of them?
- Who are the most / least loyal customers, and how are they characterized?
- What are customers' transaction behavior patterns? Which services have customers purchased together often?Which types of mobile banking users are more likely to respond to a certain promotion mailing?
- What are the sales patterns in terms of various perspectives such as services, regions and time (weekly, monthly, quarterly, yearly and seasonally), and so on? and
- What are the user segments in terms of various perspectives(D. Chen et al., 2012)?

  In order to address these marketing concerns, data mining techniques have been widely adopted,coupled with a set of well-known businessmetrics about customers' profitability andvalues, for instance, the recency, frequencyand monetary (RFM) model, and thecustomer life value model(D. Chen et al., 2012).

In this article a case study of using datamining techniques in customer-centricbusiness intelligence for a bankwas presented. The main purpose of this analysis is to helpthe bank better understand its mobile banking customersand therefore conduct customer-centricmarketing more effectively. On the basisof anewsegmentation model, customers of the bank have been segmented into variousmeaningful groups. Accordingly, a set ofrecommendations was provided to thebank on customer-centric marketing (D. Chen et al., 2012).

II. LITERATURE SURVEY

Banks operate in a competitive environment facing challenges in customer acquisition and service costs. In such an environment, the understanding and prediction of customer behavior in usage of services is becoming an important subject. The banks' intention is to shift customers to technology enabled self-service channels like ATMs, internet banking and more recently onto mobile banking services. Customers, these days are more and more pressed for time and they seek a channel that offers them convenience of anytime, anywhere banking and mobile banking services fits the bill very well. In Iran,mobile banking services seem to be high on priority for banks (Thakur, 2014).

Particularlyin Iran, banking services on mobile banking were launched few years ago yet the usage of such services has not reached thedesired level.Therefore, it becomes more important to look for the customer segments. The studies conducted on bank information technology adoption render insufficient information about customer segmentation(Sangle & Awasthi, 2011). In this regard the current study tends to emphasize customer data mining framework and identify the mobile user segments.

2.1. Mobile Banking

While the use of branch-based banking is still very popular, banks have other ways of providing customers with financial management services and one of them is mobile banking (Govender & Sihlali, 2014). The mobile phone as a channel for service consumption offers enormous potential since today, a mobile phone is an integral part of customers' life and a growing number of these devices are also equipped with internet connection. Currently mobile banking services enable consumers, for example, to request their account balance and the latest transactions of their accounts, to transfer funds between accounts, to make buy and sell orders for the stock exchange and to receive portfolio and price information(Laukkanen, 2007).Hence it is necessary to investigate mobile banking customer segments.

2.2. Cross-sellingAnalysis

The rationale for cross-selling, defined in the introduction as "the strategy of selling other products to a customer who has already purchased a product from the vendor" isnot only to "increase the customer's reliance on the company and decrease thelikelihood of switching to another provider" but also to exert a generally positiveinfluence on the relationship with the customer, strengthening the link betweenprovider and user (Kamakura, Wedel, De Rosa, & Mazzon, 2003). Increasing product holding leads to anincreased number of connection points with customers, as well as increasing theswitching costs they would face if they decided to take their custom elsewhere.Increased product holding also creates a situation in which the company can get toknow it customers better through a greater understanding of buying patterns andpreferences. This, in turn, puts it in a better position to develop offerings that meetcustomer needs. Consequently, it is argued that cross-sellingincreases the total value of a customer over the lifetime of the

relationship(Ansell, Harrison, & Archibald, 2007; Kamakura et al., 2003).
Cross-selling, and consequently cross-buying, is receiving considerable attention inboth research and management in the financial services industry. Denoting to termssuch as "bancassurance" and "allfinanz", i.e. the sales of insurance products by banks, and on the other hand "assurfinance", i.e. the salesof financial products by insurance companies, changes in the market such as deregulation and increasingcompetition have driven the once traditional financial service providers towardsincreasing provision of integrated financial services, that is, offering their customers aseamless service of banking, investment and insurance products(Mäenpää, 2012; Van den Berghe & Verweire, 2001).

2.3. Bank customer segmentation

Market segmentation has become one of the most dominant concepts in both marketing theory and practice. In banking industry, like any other service industries, segmentation is considered as a major way of operationalizingthe marketing concept, and providing guidelines for a bank's marketing(Edris, 1997). As theory, market segmentation is the process of dividing a market into distinct groups of individuals, or organizations, who share one or more similar responses to some elements of the marketing mix. The segmentation process calls for dividing the total market into homogeneous segments, selecting the target segments, and creating separate marketing programs to meet the needs and wants of these selected segments(Edris, 1997).
The identification of segments allows the evaluation and refinement of a bank's marketing strategy. The effectiveness of the segmentation process and strategy depends on identifying segments that are measurable, accessible, stable, substantial, and actionable(Edris, 1997).

2.4. CLV and RFM Analysis

Customer segmentation is used in differentsettings, for instance, using customer segmentationfor estimating customer future valueas a part of customer lifetime value (CLV) in banking scope (Khobzi, Akhondzadeh-Noughabi, & Minaei-Bidgoli, 2014). Generally, customersegmentation is often used to obtain moredetails about different customers in bankingscope. Actually, according to these studiesdiverse groups of banks' customers are identified by segmenting based on customers' financial transactions(Khobzi et al., 2014).

RFM analysis is a widely used method thatidentifies customer behavior and representscustomer behavior characteristics, and it standsfor the words: Recency, Frequency, and Monetary.Generally, these parameters are defined asfollows(Khobzi et al., 2014):

- Recency: The interval between the purchase and the time of analysis.
- Frequency: The number of purchases within a certain period.
- Monetary: The amount of money spent during a certain period.

These definitions are adaptable and can varyin different cases. In recent years, several researcherstried to extend the concept of RFManalysis, but there is lack of studies that analyze the customer segments and RFM analysis focusing banks over the mobile banking platform. Thus, although the increasing competitiveness in mobile banking is motivating an exponential growth in the number of studies, there is a call for studies that will help us to understand how customer behavior are formed in the mobile banking business in greater detail.

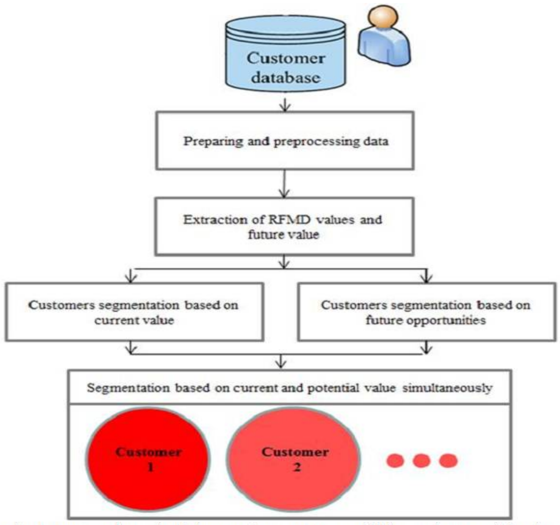

Fig. 1. Research methodology using RFMD variables and potential value.

Moreover, the rapid development of data mining methodsenables using large data bases of customer data toextract the knowledge, supporting marketing decisionprocess. Asthe ability to acquire new customers and retain existing iscrucial, especially in the finance marketplace, thepossibility of customer segmentation by obtaining theinformation on unknown hidden patterns has a majorsignificance. Until now only few papers present usingof data mining techniques in banks. In ourwork, we consider application of a new RFM segmentation algorithmin this area(Zakrzewska & Murlewski, 2005).

III. METHODOLOGY

In this study, numbers of mobile banking users of a major bank in Iran were studied. These user demographics were shown in table I. Additionally, bank customer table was shown in table II.The proposed methodology utilizeda new segmentation methodology, as shown in Fig. 1. In this work, customer priority number (CPN) or RFMD as a new model of RFM, was introduced for first time. It is the product of the recency (R), frequency (F), average transaction amount or monetary (M) and customer deposit (D) ratings: RFMD = R × F × M×D

The rationale ofthe proposed approach is that if customers have hadsimilar purchasing behavior, then theyare very likely also to have similar RFMD values. RFMD values were used tocluster customers into groups with similar RFMD values. The scaling of R–F–M-D attributes was shown in table III.

TABLE I. Demographics of mobile banking users

Education	Percent (%)	Occupation	Percent (%)	Gender	Percent (%)	Age	Percent (%)
High school	0.56	Employee	0.364	Male	0.804	Young	0.36
College	0.34	Business	0.397	Female	0.196	Middle	0.578
Master and above	0.1	Engineer	0.054			Old	0.062
		Manager	0.016				
		Student	0.07				
		Physician	0.07				
		Faculty	0.01				
		Others	0.019				

TABLE II. Customer table.

Field Name	Data Type	Description	Value set
ID	Text	Customer ID code	-
Acct-NO	Text	Customer account number	-
Birth-Date	Text	Below 30; 30–40; 40–60; 60 and above	{Y, M, O}
Sex-code	Text	Gender	{F, M}
Marital_Status	Yes/No	-	{Y, N}
Education	Text	High school and below; college; master and above	-
Occupation	Text	Manager; employee of company; student; others	-
Operator-Network	Text	IR-TCI; MTN-Irancell; Talya	{I, M, T}
Service Type	Text	e.g. Payments, Transfers, Payments & Transfers	-
Open-Date	Date/Time	Account opening date	-
Amount	Number	-	-
Transaction-Date	Date/Time	-	-
Balance	Number	Account status	-

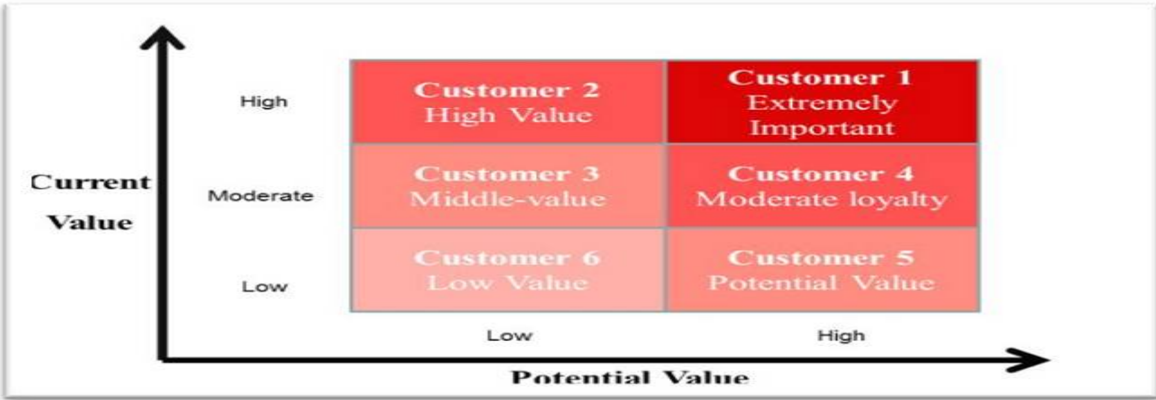

Fig. 2. Customer segmentation result based on CLV

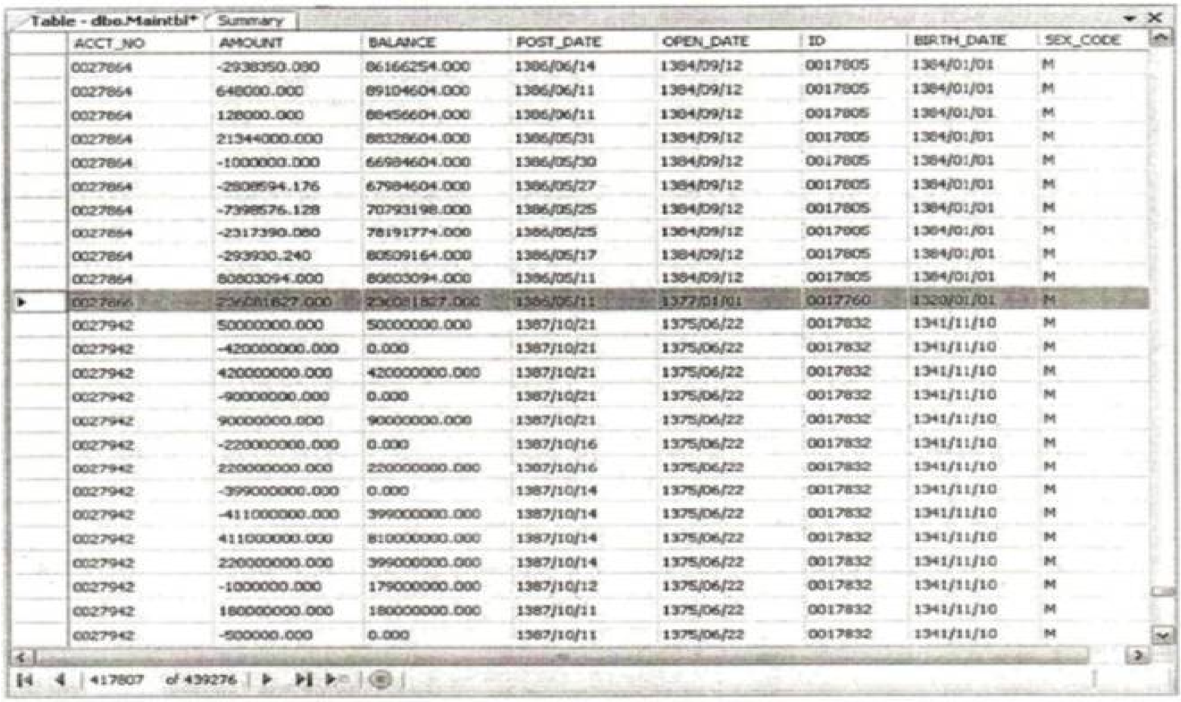

Table - dbo.Maintbl* | Summary

	ACCT_NO	AMOUNT	BALANCE	POST_DATE	OPEN_DATE	ID	BIRTH_DATE	SEX_CODE
	0027864	-2938350.080	86166254.000	1386/06/14	1384/09/12	0017805	1384/01/01	M
	0027864	648000.000	89104604.000	1386/06/11	1384/09/12	0017805	1384/01/01	M
	0027864	128000.000	88456604.000	1386/06/11	1384/09/12	0017805	1384/01/01	M
	0027864	21344000.000	88328604.000	1386/05/31	1384/09/12	0017805	1384/01/01	M
	0027864	-1000000.000	66984604.000	1386/05/30	1384/09/12	0017805	1384/01/01	M
	0027864	-2808594.176	67984604.000	1386/05/27	1384/09/12	0017805	1384/01/01	M
	0027864	-7398576.128	70793198.000	1386/05/25	1384/09/12	0017805	1384/01/01	M
	0027864	-2317390.080	78191774.000	1386/05/25	1384/09/12	0017805	1384/01/01	M
	0027864	-293930.240	80509164.000	1386/05/17	1384/09/12	0017805	1384/01/01	M
	0027864	80803094.000	80803094.000	1386/05/11	1384/09/12	0017805	1384/01/01	M
▶	0027866	236081627.000	236081827.000	1386/05/11	1377/01/01	0017760	1320/01/01	M
	0027942	50000000.000	50000000.000	1387/10/21	1375/06/22	0017832	1341/11/10	M
	0027942	-420000000.000	0.000	1387/10/21	1375/06/22	0017832	1341/11/10	M
	0027942	420000000.000	420000000.000	1387/10/21	1375/06/22	0017832	1341/11/10	M
	0027942	-90000000.000	0.000	1387/10/21	1375/06/22	0017832	1341/11/10	M
	0027942	90000000.000	90000000.000	1387/10/21	1375/06/22	0017832	1341/11/10	M
	0027942	-220000000.000	0.000	1387/10/16	1375/06/22	0017832	1341/11/10	M
	0027942	220000000.000	220000000.000	1387/10/16	1375/06/22	0017832	1341/11/10	M
	0027942	-399000000.000	0.000	1387/10/14	1375/06/22	0017832	1341/11/10	M
	0027942	-411000000.000	399000000.000	1387/10/14	1375/06/22	0017832	1341/11/10	M
	0027942	411000000.000	810000000.000	1387/10/14	1375/06/22	0017832	1341/11/10	M
	0027942	220000000.000	399000000.000	1387/10/14	1375/06/22	0017832	1341/11/10	M
	0027942	-1000000.000	179000000.000	1387/10/12	1375/06/22	0017832	1341/11/10	M
	0027942	180000000.000	180000000.000	1387/10/11	1375/06/22	0017832	1341/11/10	M
	0027942	-500000.000	0.000	1387/10/11	1375/06/22	0017832	1341/11/10	M

417807 of 439276

Fig. 3. The partial data of C-Bank dataset

TABLE VI. Segmentation results

ID	RFMD	Current Value	Potential Value	Customer Type or Segment	Segment	Marketing Strategy
0017805	108	High	High	Customer 1	Extremely important	Relationship management
0017760	12	Low	High	Customer 5	Potential value	Retention
0017832	24	Low	Low	Customer 6	Low value	Growing

TABLE III. The scaling of R–F–M-D attributes

Field Name	Description	Value set
ID	-	-
Recency	Below 15; 16~30; 31 and above (day)	{3, 2, 1}
Transaction Frequency	Below 5; 5~20; 21 and above (in a fiscal year)	{1, 2, 3}
Transaction amount average	NT$100 and below; 100~1,000; 1,001~3,000; 3,001 and above	{1, 2, 3, 4}
Deposit Average	NT$1,000 and below; 1,001~7,000; 7,001~20,000; 20,001 and above	{1, 2, 3, 4}

TABLE V. RFMD values for each customer

ID	Acct-NO	Recency	Transaction Frequency	Transaction amount average	Deposit Average	R	F	M	D
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
0017805	0027864	10	30	1200	41000	3	3	3	4
0017760	0027866	8	4	450	5120	3	1	2	2
0017832	0027942	25	12	150	15000	2	2	2	3
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.

RFMD refers to the customer current value. It calculated for each stored customer data (Table II). RFMD or CPN ranking was illustrated in table IV.The rankings given are normally scored on a scale of 1-4. Therefore, CPN would be between 1 and 144. After the case priority number (CPN)was computed, customer current value could be determined.After RFMD computation, potential value of customer

based on future opportunitiesshould be estimated.
The CPN and potential value of customer are main elements for customer segmentation (Fig. 2).

TABLE IV. Suggested CPN table for customer current value

Segment	Value
High value	81~144
Moderate	36~80
Low	1~35

IV. CASE STUDY

This workconsidered a bankcustomer records to conduct empirical research (Fig. 3). Three customers were selected to show methodology effectiveness. The real data of selected customers and related R, F, M, and Ds were shown in table V. RFMDs were computed and customer potential values were illustrated in table V. Meanwhile customer type and its marketing strategy were derived (Table VI).

V. MANAGERIAL IMPLICATIONS

The bank's marketing and business manager, bank branch manager, or analysts can employ the segments to:

- Better understand customers. The bank can track changes to customers' life styles. Better customer knowledge and understanding are the cornerstones of effective and profitable customer management(Zuccaro & Savard, 2010).
- Enhance the value of segmentation systems. Proactive segmentation systems are enhanced when they are updated regularly. This means that both demographic and transaction data are integrated into an ongoing process of customer segment management. Customer segments possess the built-in capacity to integrate demographic and transaction data. Up-to-date and relevant segmentation system provide the bank with invaluable data to plan new service offerings, predict customer reaction and determine profit levels on a segment-by-segment basis. Segmentation system enhances the bank's capacity to employ customer knowledge in a more strategically effective manner(Zuccaro & Savard, 2010).
- Improve marketing effectiveness. Without a sound segmentationsystem a bank would not be able to perform valid and reliable customerprospecting which in turn would seriously undermine the effectiveness andprofitability of customer targeting. The starting point for serious customerprospecting and targeting is the bank's customer data and transaction database.It provides the analyst with invaluable behavioral information (use of mobile banking by each customer). In addition, the database will contain rudimentarysocio-demographic data such as the customer's age, sex, maritalstatus and some employment information. Customer prospecting and targetingcould be undertaken employing such data. Customers would be placed in groups. Many organizations have realized that byenhancing their customer database they can significantly improve their customer prospecting and increase the lift ofcustomer targeting strategies. Thus, segmentation is designed to exploit thepotential of the bank's customer database. Once a specific customer segmentgenerated by RFMDsegmentation has been identified, it becomes relativelysimple to identify the customer prospects and target them with the appropriatestrategy and promotional tools(Zuccaro & Savard, 2010).
- Develop effective communications. In the age of segmentation, developingan effective communication strategy is not a simple task. The nature and varietyof potential communication messages and media to transmit the messages hasgrown exponentially during the last two decades. In addition, mostorganizations, including banks, are abandoning traditional communicationmedia such as television and radio and opting for more specialized vehicles suchas the web. Segmentation provides the bank with a richer set of segments that can be described with animpressive level of detail. The refined segments along with detailed financial life style of its membersallow the bank to design tailor-made communication strategies(Zuccaro & Savard, 2010).

CONCLUSION

Mobile phone handsets, which were initially used almost exclusively for voice calls are now often used to transmit data and undertake commercial transactions. In recent years, mobile phones have become very popular with a penetration rate in many of states of Iran. The term m-commerce has been widely used to describe a subset of e-commerce and refers to transactions with monetary value that are conducted via mobile devices(Koenig-Lewis et al., 2010).

Iranian banks today face intense competition inside and outside Iran. This in turn has forced these banks to be more oriented towards their customers. The main focus of this study was on the customer segmentation. Banks which are marketing-oriented are notonly required to be aware of the needs of theircustomers, but they should be able to satisfyeffectively the needs of each identified customersegment. This study provides evidencethat segmentation of the customers is of great importance to banks inorder to identify the behavior of each segmentand provide certain marketing actions that best suitthese behaviors.The results of this study provide a practicalapproach to Iranian banks that wouldhelp in determining the true segments of mobile banking customers(Edris, 1997).

Furtheremore, one of the important factors for the success of a bank industry is to monitor their customers' behavior. The bank needs to know its customers' behavior to find interesting ones to attract more transactions which results in the growth of its income and assets.

The RFM analysis is an approach for extracting behavior of customers and is a basis for marketing and CRM, but it is not aligned enough for banking context(Bizhani & Tarokh, 2011). So, this study introducednew RFM model toimprove understanding of bank customers.

Furthermore, this paper presented a framework of segmentation by applying it to the customers of one of Iran's major banks. Also, this paper presented a synthesized example of segmentation in the banking sector.The proposed model improved current understanding of mobile banking customers. Meanwhile, from a practical perspective, insights provided by the study can help mobile banking managersto managemobile users' behavior.

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ADVANTAGE OF MAKE-TO-STOCK STRATEGY BASED ON LINEAR MIXED-EFFECT MODEL

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Abstract- In the past few decades, demand forecasting becomes relatively difficult because of the rapid changes of world economic environment. In this research, the make-to-stock (MTS) production strategy is applied as an illustration to explain that forecasting plays an essential role in business management. We also suggest that linear mixed-effect (LME) model could be used as a tool for prediction and against environment complexity. Data analysis is based on a real data of order quantity demand from an international display company operating in the industry field, and the company needs accurate demand forecasting before adopting MTS strategy. The forecasting result from LME model is compared to the common used approaches, times series model, exponential smoothing and linear model. The LME model has the smallest average prediction errors. Furthermore, multiple items in the data are regarded as a random effect in the LME model, so that the demands of items can be predicted simultaneously by using one LME model. However, the other approaches need to split the data into different item categories, and predict the item demand by establishing model for each item. This feature also demonstrates the practicability of the LME model in real business operation.

Index Terms- forecasting, linear mixed-effect model, make-to-stock, order demand, production strategy

I. INTRODUCTION

Demand forecasting is crucial for supply chain management. Production planning, inventory management, and manufacturing scheduling are typically formulated according to short- and long-term expected demand [1]. To reduce the occurrence of delivery delays caused by the "crowding out" effect of manufacturing processes, contemporary enterprises have gradually changed their production patterns from make-to-order (MTO) to make-to-stock (MTS), and increasingly fewer enterprises are using the MTO production strategy [2 , 3]. The MTO production involves commencing product production only after the customer places the order. The MTS production pattern entails a stocking-up production, in which a company manufactures products and stores them in inventory before customer orders are received. Subsequently, the company sells its stock as customer places orders. If a company receives orders requesting a high mix of products but in low volumes, it must be capable of forecasting their order demand accurately before attempting an MTS production strategy. Accordingly, the advantages of the MTS production strategy—including quick delivery, arranging a long-term manufacturing schedule, reducing the stock levels, and stabilizing product prices—can be realized. Worldwide, variation in customer demand has forced many manufacturers to adopt a high-mix low-volume production model. However, this type of enterprise is not as efficient as a low-mix high-volume enterprise. Therefore, determining how high-mix low-volume enterprises can enhance their business operation performance urgently requires a solution. Hence, accurately forecasting order demand is a fundamental to successfully applying the MTS production strategy to a high-mix low-volume business operation model. Because inaccurate demand forecast is a concern for high-mix low-volume enterprises, the MTO production strategy is typically adopted. However, this production pattern increases financial risks and requires a long delivery time, making centralized production difficult, which subjects production lines to frequent changes, resulting in high operating costs and low product quality. Complex operations are the primary cause of human error and low job satisfaction. Therefore, if the inefficiency of the high-mix low-volume business operation model cannot be solved, then, despite a high business revenue, business operation costs would increase rapidly, product quality would reduce, and employee job satisfaction and customer satisfaction would decrease, which result in that business development would stagnate. Therefore, the forecasting method proposed in this study can provide a crucial basis for transitioning from using the MTO to the MTS production, and may offer a viable solution for improving the business operation performance of high-mix low-volume enterprises. The application and improvement of the proposed forecasting method can assist researchers with understanding the characteristics of business operations and construct related business operation models. Forecasting ability depends on crucial information and reliable forecasting methods. In recent years, demand forecasting has become increasingly complex, primarily because the global economic environment has gradually changed. The underlying reasons for this change can be explained in terms of the following four dimensions: volatility, uncertainty, complexity, and ambiguity (VUCA) [4 , 5 , 6], all of which have been shown to influence demand forecasting [7]. Volatility means that new products are rapidly developed, product lifecycles are shortened, customer preferences change suddenly, and organizations are frequently restructured; consequently, historical data diminishes in value. Uncertainty refers to unknown factors that cause sudden shifts in demand, and these factors are generally regarded as outliers or interferences. Complexity means that the interaction of these influential factors cannot be modelled easily, and ambiguity refers to fuzzy events and situations that cannot be quantifiably defined, leading to the loss of key influential factors. In summary, according to the influence of economics on demand forecasting, developing a reliable forecasting method requires analyzing whether historical data can contribute to demand forecasting, and whether the effects of influential factors can be identified. To meet the requirements of modern forecasting methodologies, this study proposed using linear mixed-effect models to perform forecasting. Linear mixed-effect models have been extensively developed and widely applied in various fields. However, no study has used this model to forecasting in business operation. Linear mixed-effect models are characterized by the inclusion of temporal factors and explanatory variables and the analysis of their significance. Accordingly, crucial influential factors can be identified to forecast demand. These characteristics fulfill the requirements of modern forecasting methodologies and can be used as the basis for companies to improve their operation efficiency and to develop competitive advantages. The following sections explore the influences of the MTO and MTS production strategies on business operation as well as the role of forecasting in the MTS strategy, provides a review of the literature on forecasting methodologies, and summarizes the strengths and weaknesses of commonly used forecasting methods. In addition, the proposed linear mixed-effect model as well as a method for model parameter estimation are introduced. Subsequently, the order demand of a manufacturer in central Taiwan is forecasted using product type as a crucial explanatory variable. Specifically, the linear mixed-effect model is applied to forecast the order demand for 20 individual product types. A 1-year forecast of monthly demand is reported, and three types of forecast errors are used to assess the forecasting ability of the model. The results show that the forecasting ability of the linear mixed-effect model in an empirical analysis is superior to those of a linear forecasting model, exponential smoothing method, and time-series forecasting method.

II. LITERATURE REVIEW

A. Influences of the MTO and MTS on Business Operations

Modern production strategies primarily involve two main production patterns: the MTO (based on customer orders), and the MTS (based on production capacity) [8]. From the perspective of customers, one competitive advantage of the MTS production is short delivery time and quick response [9]. Therefore, identifying the types of products that are specifically suitable for the MTS production pattern or both MTS and MTO patterns is a favored research topic in management science [8].

Regarding the influences of the MTO and MTS production strategies on business operations, Hendry and Kingsman [10] showed that the MTS and MTO production strategies are mostly used for manufacturing standard and customized products, respectively. Regarding the attributes of orders, order demand for MTS products is generally predictable, whereas that for MTO products is irregular and unpredictable. Concerning production planning, MTS production lines operate according to forecast results, and the production line schedule can be adjusted easily. However, the schedule of MTO production lines is determined based on recent order demand, and long-term manufacturing schedules are difficult to determine. In terms of product delivery, enterprises that adopt the MTS production strategy can ensure rapid product delivery, thus maintaining high customer satisfaction. The MTO production pattern requires long delivery times, and enterprises adopting this strategy must communicate with customers to achieve consensus regarding product delivery time. Concerning product price, compared with prices of products produced adopting the MTO strategy, the prices of MTS-produced products are relatively more stable. Soman, van Donk, and Gaalman [8] indicated that the MTO production pattern is effective for handling orders requesting high-mix customized products; the production planning for the MTO strategy must prioritize meeting order demands, while production effectiveness is determined according to crucial elements in the orders (e.g., the expected delivery volume and number of delayed delivery days). The goal of a company that manufactures MTO products is to shorten product delivery times; production efficiency emphasizes the importance of capability planning, orders that are lost due to problems with manufacturing processes, and on-time product delivery. By contrast, the MTS production pattern is effective for handling uniform product specifications and less customized products, where production planning is determined based on product demand forecasting and production effectiveness is production-oriented. Therefore, the goal of a company manufacturing MTS products is to enhance product availability, and its production efficiency emphasizes the importance of inventory policy, finished goods inventory, one-off or batch production, and accurate demand forecast. Rajagopalan [11] indicated that inventory costs are slightly higher for the MTS strategy than for the MTO strategy, particularly for one-off and batch production.

In summary, the MTS strategy relies heavily on the accuracy of product demand forecasting. Because of accurate forecasting, the advantages of the MTS production strategy, including short delivery time, manageable long-term manufacturing schedule, and stable product prices, can be realized. In addition, accurate forecasting can optimize inventory levels; therefore, companies applying the MTS strategy can effectively control inventory costs. Some researchers have explored the inventory policies and material control mechanisms in MTO production [12]. The forecasting method proposed in this study provides a relatively accurate basis for forecasting random customer orders (demand) for MTS production.

B. Forecasting Methodology

Two main types of forecasting methodology exist: (1) statistical methods; and (2) data mining and machine learning [13]. Both types of forecasting methodology are aimed at identifying the relationship between influential factors (independent variables) and research variables (dependent variables), and identifying the effects of the influential factors on research variables [7]. These two methodologies involve distinct approaches to interpreting analysis models. The statistical methodology is based on the data derived from a specific mathematical model as well as unobservable errors. The machine-learning methodology avoids fitting data to a specific model and develops algorithms that are suitable for various types of data. These two methodologies differ in their strengths and characteristics [13]. The statistical methodology uses the probability distribution of errors to infer the significance of the influential factors in a model. The reliability of inferences correlates positively with the mathematical model. The machine learning methodology uses the size of forecast errors as a basis for selecting the optimal forecasting model.

Several typical forecasting methods are introduced as follows, the characteristics of which are shown in Table 1. The exponential smoothing method was proposed by Holt [14] and the statistical theoretical foundation for this method was established by Muth [15]. This method involves using a demand observation and predictive value in the current period to determine the predictive value for the subsequent period by using weighted mean. To date, the exponential smoothing method has been widely applied to forecast demand under the bullwhip effect [16] and to plan inventory control strategies [17]. Moreover, the methodology for exponential smoothing has been developed in recent years into one that incorporates the effect of influential factors on the accuracy of demand forecasts [7, 18, 19]. Wang [19] used a model selection method where crucial influential factors were included in the selected model, and nonsignificant factors were removed to avoid over-fitting the model.

Time-series model was first developed in the nineteenth century, and past studies related to such model were then systematically compiled by Box and Jenkins [20] into a book. A time-series autoregressive integrated moving average (ARIMA) model integrates an autoregressive process and moving average process after obtaining a finite difference from time-series data. The ARIMA model is used to estimate the correlations parameter between the time points of observed values, and the estimated parameter

Table 1. CHARACTERISTICS OF F ORECASTING M ETHODS . (○: YES ; △: YES FOLLOWING MODIFICATION BY OTHER STUDIES

Forecasting method	Can handle temporal data	Can include influential factors	Analyzing the importance of influential factors (e.g., *p* value)
Linear mixed-effect model	○	○	○
Exponential smoothing method	○	△	△
ARMA	○	△	△
Linear model	△	○	○

values can then be used for forecasting. Subsequently, Box and Tiao [21] added other time-series influential factor to the ARIMA model. Pankratz [22] called this model the dynamic regression model.

Linear regression models are a type of linear model that are most frequently mentioned in statistical analyses. Linear models assume that research variables and influential factors are linearly related, and thus can be used to explore the effect of influential factors on research variables. Furthermore, linear models assume that observation values are mutually independent; thus, this model is applicable for analyzing data containing mutually independent observation values. If linear models are used to analyze time-correlated data, i.e., the observation values being correlated over time, then unbiased but invalid model coefficient estimators can be obtained. Consequently, the standard errors of the model coefficient estimators would be incorrect, and problems regarding statistical testing within the models arise, such as whether the model coefficients are significantly greater than 0, whether the models exhibit explanatory power, and whether the predictive intervals are reliable in forecast analysis [23, 24].

Linear mixed-effect models can be considered as an extension of linear models. The linear mixed-effect models add random effects to linear models with fixed effects. Hence, a model that has both fixed and random effects is called a linear mixed-effect model. Linear mixed-effect models are typically used to describe the relationship between research variables and categorical factors with correlated observation values. A characteristic of the mixed-effect models is that observation values at the same categorical level have identical random effect values for dependent variables; observation values at different levels have distinct values of random effect. This characteristic explains the correlation between observation values at an identical level. Therefore, linear mixed-effect models differ considerably from linear models. The mixed-effect model can be applied to data where observation values are correlated (e.g., longitudinal data, repeated measures data, and multilevel data). However, linear models can be applied only to data where the observation values are mutually independent. In industrial operations, the pattern of data observations is often time-correlated. For example, when forecasting monthly product demand or monthly inventory levels, the observation values are correlated over time. Under such circumstances, the linear mixed-effect model is more accurate than linear models for identifying statistically significant factors.

In the past 2 years, the linear mixed-effect model has been broadly applied in various fields, such as the timber industry [25], medicine [26, 27], and ecology [28], to identify crucial influential factors. In addition, numerous studies have established models for forecasting [29, 30]. However, in industrial engineering and management science [24, 31, 32, 33], no study has used the linear mixed-effect model to make predictions by using time-correlated data or to identify key influential factors. Therefore, in this study, a linear mixed-effect model was applied to business operations to analyze the importance of influential factors, and to forecast product demand; in addition, the performance of the linear mixed-effect model was compared with that of other methods, which are the research contributions of this study.

III. LINEAR MIXED-EFFECT MODEL

According to parameter attributes, two types of effect exist in a linear mixed-effect model: fixed and random effects [34, 35]. In a linear model, the parameters are all fixed values and therefore its corresponding covariates are referred to as fixed-effect parameters. The fixed effect describes the true value of the coefficient for an entire population, or the true value of the coefficient for a factor that can be repeatedly tested under identical conditions. If a factor in a model exhibits a random effect, then the factor is sampled from an entire population. The random effect is a coefficient of the factor; moreover, the coefficient is a random variable and not a fixed value. The following section introduces the linear mixed-effect model developed by Laird and Ware [36] and the estimation of model parameters, and describes how the research variables are forecasted.

A. Linear Mixed-Effect Model

In contrast to a multilevel model, a single-level linear mixed-effect model [36] was employed in this study. The multilevel model differs from the single-level model in terms of the covariance matrix of the observation values. The single-level model involves only one level, whereas the multilevel model involves at least two levels. The covariance matrix of the multilevel model is more complex than that of the single-level model. In practice, whether using a single-level or multilevel model is more appropriate depends on the data structure of the observation values. Although the covariance matrices of the two models differ, the observation values of the various groups at a fixed level are independent of each other, and the within-group observation values are intercorrelated. In the multilevel model, a group at one hierarchy level becomes the next level of the hierarchy.

The single-level linear mixed-effect model developed by Laird and Ware [36] is expressed as follows:

$$\mathbf{y}_i = \mathbf{X}_i\boldsymbol{\beta} + \mathbf{Z}_i\mathbf{b}_i + \boldsymbol{\varepsilon}_i, \quad i = 1, \ldots, M \tag{1}$$

$$\mathbf{b}_i \,\square\, N(\mathbf{0},\ \boldsymbol{\Psi}),\ \boldsymbol{\varepsilon}_i \,\square\, N(\mathbf{0},\ \boldsymbol{\Lambda}_i), \tag{2}$$

where $\mathbf{b}_i$ is a matrix that is independent of $\boldsymbol{\varepsilon}_i$ (index i denotes the ith group at a single level), $\mathbf{y}_i$ contains n_i observation values for the ith group, M denotes the number of groups, $\boldsymbol{\beta}$ denotes a p -dimensional vector for the fixed effect, $\mathbf{b}_i$ denotes a q -dimensional vector for the random effect, $\mathbf{X}_i$ denotes an $n_i \times p$ covariance matrix for the fixed effect, $\mathbf{Z}_i$ is an $n_i \times q$ covariance matrix for the random effect, and $\boldsymbol{\varepsilon}_i$ denotes an n_i -dimensional within-group random error term. The variable $\boldsymbol{\varepsilon}_i$ obeys a multivariate normal distribution with an expected value of 0 and a covariance matrix of $\boldsymbol{\Lambda}_i$, and $\mathbf{b}_i$ obeys a multivariate normal distribution with an expected value of 0 and a covariance matrix of $\boldsymbol{\Psi}$. The model assumes that $\boldsymbol{\varepsilon}_i$ and $\boldsymbol{\varepsilon}_j$ are mutually independent ($i \neq j$); in addition, $\boldsymbol{\varepsilon}_i$ and $\mathbf{b}_i$ are mutually independent. Therefore, considering Models (1) and (2), the covariance matrix of the within-group observation values $\mathbf{y}_i$ is expressed as follows:

$$\mathbf{V}_i \equiv \mathrm{Var}(\mathbf{y}_i) = \mathrm{Var}(\mathbf{Z}_i\mathbf{b}_i) + \mathrm{Var}(\boldsymbol{\varepsilon}_i) = \mathbf{Z}_i\boldsymbol{\Psi}\mathbf{Z}_i^T + \boldsymbol{\Lambda}_i \tag{1}$$

where the nondiagonal elements of $\mathbf{V}_i$ are not required to be 0. Therefore, according to (3), Models (1) and (2) allow the existence of the correlation between observation values within a group. This is a major difference that the two models have with the linear model.

B. Estimation of the Model Parameters

This section introduces estimation methods that adopt the linear mixed-effect model: the maximum likelihood (ML) and restricted ML (REML) estimation methods. Regarding the ML method, the estimates of ML estimators are those that reach the maximum value of ML functions. By comparison, the REML method is aimed at identifying the estimators that exhibit unbiased characteristics. Therefore, estimators obtained using the REML method are unbiased, whereas those derived using the ML method could feature either biased or unbiased property. Therefore, most researchers prefer the REML method [34, 35]. We introduce the estimation procedures for both of these estimation methods, although only the REML method was used in this study.

First, the model $\boldsymbol{\beta}$ coefficient and covariance matrix of observation values $\mathbf{V}_i$ are estimated as follows. In Models (1) and (2), the expected values of $\mathbf{b}_i$ and $\boldsymbol{\varepsilon}_i$ are assumed to be 0; thus, the expected value of y_i is $X_i\beta$ (i.e., $E(\mathbf{y}_i) = \mathbf{X}_i\boldsymbol{\beta}$). Because the covariance matrix of y_i is V_i (i.e., $Var(\mathbf{y}_i) = \mathbf{V}_i$) and because $\mathbf{b}_i$ and $\boldsymbol{\varepsilon}_i$ obey an independent multivariate normal distribution, the marginal distribution of y_i is a multivariate normal distribution expressed as follows:

$$\mathbf{y}_i \sim N(\mathbf{X}_i\boldsymbol{\beta},\ \mathbf{V}_i)$$

The ML function is expressed as follows:

$$L(\boldsymbol{\beta},\boldsymbol{\theta})=\prod_{i=1}^{M}(2\pi)^{\frac{-n_i}{2}}\det\left(\mathbf{V}_i\right)^{\frac{-1}{2}} \times\exp\left\{-\frac{1}{2}(\mathbf{y}_i-\mathbf{X}_i\boldsymbol{\beta})^T\mathbf{V}_i^{-1}(\mathbf{y}_i-\mathbf{X}_i\boldsymbol{\beta})\right\}$$

where $\boldsymbol{\theta}$ denotes the set of $\mathbf{V}_1,...,\mathbf{V}_M$. To facilitate differentiation, the natural logarithm of the ML function is used instead of the ML function to evaluate the ML and REML estimators, and define $l(\boldsymbol{\beta},\boldsymbol{\theta}) = \ln L(\boldsymbol{\beta},\boldsymbol{\theta})$.

ML estimation method The ML estimates of β and θ are the values that maximize $l(\boldsymbol{\beta},\boldsymbol{\theta})$ and thus are also the values that maximize L(β,θ). Calculating the maximum value of $l(\boldsymbol{\beta},\boldsymbol{\theta})$ is challenging. Typically, let $\boldsymbol{\theta} = \hat{\boldsymbol{\theta}}$, and evaluate the value of β such that it maximizes $l_{\boldsymbol{\theta}=\hat{\boldsymbol{\theta}}}(\boldsymbol{\beta},\boldsymbol{\theta})$. Subsequently, let $\boldsymbol{\beta} = \hat{\boldsymbol{\beta}}$, and calculate the value of θ such that it maximizes the value of $l_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}(\boldsymbol{\beta},\boldsymbol{\theta})$. This process is iterated until the change in $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\theta}}$ is within a tolerance error (i.e., the $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\theta}}$ values converge).

Specifically, we first let $\boldsymbol{\theta}$ be $\hat{\boldsymbol{\theta}}$ (equivalent to letting $\mathbf{V}_i$ be $\hat{\mathbf{V}}_i$, $i = 1,...,M$). Under these conditions, $\mathbf{y}_i$ obeys $N(\mathbf{X}_i\boldsymbol{\beta},\hat{\mathbf{V}}_i)$. An analytical solution for $\boldsymbol{\beta}$ can be obtained by using the generalized least squares method.

$$\hat{\boldsymbol{\beta}} = (\sum_i \mathbf{X}_i^T \hat{\mathbf{V}}_i^{-1} \mathbf{X}_i)^{-1} \sum_i \mathbf{X}_i^T \hat{\mathbf{V}}_i^{-1} \mathbf{y}_i \qquad (4)$$

Accordingly, $l_{\boldsymbol{\theta}=\hat{\boldsymbol{\theta}}}(\hat{\boldsymbol{\beta}},\boldsymbol{\theta})$ is the maximum value. Next, fix $\boldsymbol{\beta}$ in $l(\boldsymbol{\beta},\boldsymbol{\theta})$ as $\hat{\boldsymbol{\beta}}$, denoted by $l_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}(\boldsymbol{\beta},\boldsymbol{\theta})$, to obtain a $\boldsymbol{\theta}$ that maximizes the value of $l_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}(\boldsymbol{\beta},\boldsymbol{\theta})$, where

$$l_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}(\boldsymbol{\beta},\boldsymbol{\theta}) = -\frac{1}{2}\Big(\sum_i n_i \times \ln(2\pi) + \sum_i \ln(\det(\mathbf{V}_i)) + \sum_i (\mathbf{y}_i - \mathbf{X}_i\hat{\boldsymbol{\beta}})^T \mathbf{V}_i (\mathbf{y}_i - \mathbf{X}_i\hat{\boldsymbol{\beta}})\Big) \qquad (5)$$

where $\mathbf{V}_1,...,\mathbf{V}_M$ are functions of $\boldsymbol{\theta}$. Typically, $l_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}(\boldsymbol{\beta},\boldsymbol{\theta})$ is not a linear function for $\boldsymbol{\theta}$. Consequently, no analytical solution for $\boldsymbol{\theta}$ exists, and an algorithm must therefore be used to obtain a numerical solution for $\boldsymbol{\theta}$. Commonly used algorithms include the expectation-maximization (EM) algorithm, Newton's method, and Fisher's scoring algorithm. Previous studies have described these algorithms in detail [36, 37, 38], including a comparison of their strengths and weaknesses [35]. An algorithm can be used to obtain a numerical solution for $\boldsymbol{\theta}$ (i.e., $\hat{\boldsymbol{\theta}}$), the result of which can be converted to $\hat{\mathbf{V}}_i$. Subsequently, the calculation is performed iteratively by using Equations (4) and (5) until the values of $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\theta}}$ converge.

REML estimation method The REML method is another approach for estimating $\boldsymbol{\theta}$. The REML estimate of $\boldsymbol{\theta}$ is obtained by applying an iterative method to a restricted natural-logarithm ML function.

$$l_{REML}(\boldsymbol{\theta}) = -\frac{1}{2}\Big((\sum_i n_i - p) \times \ln(2\pi) + \sum_i \ln(\det(\mathbf{V}_i)) + \sum_i (\mathbf{y}_i - \mathbf{X}_i\hat{\boldsymbol{\beta}})^T \mathbf{V}_i (\mathbf{y}_i - \mathbf{X}_i\hat{\boldsymbol{\beta}}) + \sum_i \ln(\det(\mathbf{X}_i^T \mathbf{V}_i \mathbf{X}_i))\Big) \qquad (6)$$

Regarding the difference between the restricted natural-logarithm ML function (6) and Equation (5), Equation (6) accounts for the loss in degrees of freedom. Therefore, the estimator of $\boldsymbol{\theta}$ obtained using the REML is an unbiased estimator. The REML method involves applying Equation (4) to obtain the estimator of $\boldsymbol{\beta}$. For the REML, Equations (4) and (6) are iteratively used until the values of $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\theta}}$ converge. Equation (4) is used in both the ML and REML estimation methods to estimate $\boldsymbol{\beta}$. However, the functions employed to estimate θ (i.e., the ML and REML methods use Functions (4) and (6) to estimate $\boldsymbol{\theta}$, respectively) differ between these methods, and they thus yield different values for $\hat{\boldsymbol{\theta}}$. In addition,

because $\hat{\mathbf{V}}_i$ is a function of $\hat{\boldsymbol{\theta}}$, different values are obtained for $\hat{\mathbf{V}}_i$; consequently, different $\hat{\boldsymbol{\beta}}$ values are obtained through using these two methods.
Estimating random effect parameters Given $\mathbf{b}_i$, the following equation can be derived from (1):

$$\mathbf{y}_i \mid \mathbf{b}_i \overset{d}{=} N(\mathbf{X}_i\boldsymbol{\beta} + \mathbf{Z}_i\mathbf{b}_i, \boldsymbol{\Lambda}_i)$$

where "$\overset{d}{=}$" represents "distribution equals" and $\boldsymbol{\Lambda}_i$ is given by (2). Therefore, the generalized least squares method can be applied to estimate $\mathbf{b}_i$, which is equal to $(\sum_i \mathbf{Z}_i^T\boldsymbol{\Lambda}_i^{-1}\mathbf{Z}_i)^{-1}\sum_i \mathbf{Z}_i^T\boldsymbol{\Lambda}_i^{-1}(\mathbf{y}_i - \mathbf{X}_i\boldsymbol{\beta})$. In the equation, $\boldsymbol{\Lambda}_i$ (a function of $\boldsymbol{\theta}$) and $\boldsymbol{\beta}$ are true values. Therefore, by substituting the ML or REML estimates (i.e., $\hat{\boldsymbol{\beta}}$ or $\hat{\boldsymbol{\Lambda}}_i$), we can obtain the estimator of $\mathbf{b}_i$ as follows:

$$\hat{\mathbf{b}}_i = (\sum_i \mathbf{Z}_i^T \hat{\boldsymbol{\Lambda}}_i^{-1} \mathbf{Z}_i)^{-1} \sum_i \mathbf{Z}_i^T \hat{\boldsymbol{\Lambda}}_i^{-1} (\mathbf{y}_i - \mathbf{X}_i \hat{\boldsymbol{\beta}}).$$

C. Forecasting Research Variables

After the explanatory variables $\mathbf{X}_i^{new}$ and $\mathbf{Z}_i^{new}$ have been obtained, the estimates of $\boldsymbol{\beta}$ and $\mathbf{b}_i$ (i.e., $\hat{\boldsymbol{\beta}}$ and $\hat{\mathbf{b}}_i$) described in the previous section can be used to forecast the research variable $\mathbf{y}_i$. The predictive value is as follows:

$$\hat{\mathbf{y}}_i = \mathbf{X}_i^{pred}\hat{\boldsymbol{\beta}} + \mathbf{Z}_i^{pred}\hat{\mathbf{b}}_i. \quad (7)$$

IV. A CASE STUDY

This study adopted a single-level linear mixed-effect model to forecast product demand. In the case study, the sample was a leading professional industrial LCD/OLED display manufacturer. This manufacturer produces products that are critical components of various devices used in daily life and are applied in various industries. Moreover, the company has an international customer base. Table 2 shows the number of orders, total product demand, average product demand per order, and quantity of finished goods from 2009 to 2013. Before 2013, the manufacturer produced more than 5,000 product types, and the average quantity of products required in an order was approximately 400. Thus, the manufacturer is considered to be a suitable example of a business that produces a diverse combination of high-mix products.
A characteristic of high-mix low-volume manufacturers is that they typically commence production only after receiving a customer order. This production pattern is typical of the MTO production pattern, which is mainly adopted to serve customers in niche markets. In recent years, the manufacturer's profits have decreased despite an increasing revenue and market share. Therefore, the manufacturer aimed at changing its production strategy by adopting the MTS production strategy for some product types in order to increase its batch production capacity, reduce its production costs, and improve its production efficiency. In addition, the manufacturer believed that adopting the MTS production strategy would enhance customer satisfaction by ensuring the rapid delivery of customer orders, thereby providing a competitive advantage. Thus, being able to accurately forecast product demand was crucial. Following evaluation, to test the implementation of the MTS production strategy, this study selected the top 20 standard finished products that were most frequently ordered between 2011 and 2013 by customers of the sample manufacturer. As shown in Figure 1, these 20 standard products accounted for 20% of the manufacturer turnover for standard products in 2013, with 86 orders placed in the same year. After implementing the MTS production strategy, the manufacturer planned to run production of each product type once per month per year. Accordingly, the production frequency, cost of handling orders, and frequency of changing production lines was reduced. Thus, its long-term production capacity plans can be implemented to maximize the benefits of producing a high volume of products with fewer runs.

Table 2. NUMBER OF ORDERS AND PRODUCT DEMAND

Year	Number of orders	Total product demand	Average product demand for an order	Finished goods quantity
2009	12,929	3,603,141	278.69	2,727
2010	17,968	8,343,884	464.37	3,518
2011	20,169	6,721,194	333.24	4,546
2012	22,589	8,062,890	356.94	5,822
2013	22,361	9,045,056	404.50	5,468

A. Data Structure

The data structure comprised 20 types of standard finished products. The monthly product demand data were collected from January 2007 to December 2013 for each product type (see S1 Table). The historical data before 2012 were used to estimate model parameters, and the model was used to forecast the product demand for 2013 (January–December). Not all 20 products were manufactured from 2007. The historical data used to estimate model parameters comprised 1295 observation values (64 observation values on average for each product type). The product lifecycle varied by year, and the product demand varied by month. Therefore, year and month were crucial predictors. For each type of product, the monthly product demands in each month were related. In this study, the explanatory variables (year and month) were added to the linear mixed-effect model to analyze the monthly product demand data. Regarding product sales, the product demand varied by product type. Accordingly, product type was regarded as a crucial categorical variable because of its influence in forecasting the product demand. In this study, according to the characteristics of the mixed-effect model, we used product type as a random-effect term and included the demand for each product type in a universal model to

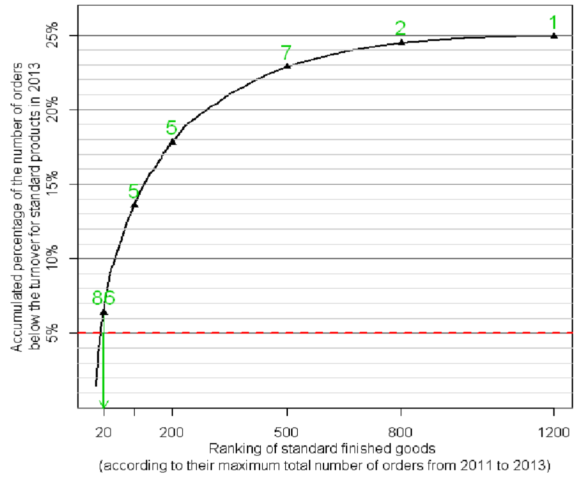

Figure 1. Maximum total number of orders (2011–2013). The plot shows that the accumulated percentage of the maximum total number of orders from 2011 to 2013 is less than the turnover of standard products in 2013. The first 20 products accounted for approximately 20% of the turnover for of standard products. The numbers in green denote the number of orders for standard products in 2013 corresponding to the horizontal axis. forecast the demand for type separately. Subsequently, we compared other commonly used forecasting methods. Unlike the mixed-effect model, other methods did not have a universal model to account for 20 unique product types. Therefore, for the other forecasting methods, the data are required to be divided into multiple data sets according to product type, and the partitioned data are then applied to the forecasting methods depending on the product type for analysis and forecasting. This approach substantially reduces the sample size, reducing the accuracy of the forecast.

B. Model Development

Product demand differed by product type, and thus we assumed the demand for each type of product to be mutually independent. In Model (1), which is the single-level model, random effect was set to be product type, thus yielding various random-effect coefficient for each product type. The model is expressed as follows:

$$\begin{aligned}\mathbf{y}_i &= \beta_0 + \beta_1 \times (\text{year-2007}) \\ &+ \beta_2 \times (\text{year-2007})^2 + \text{month} \times \boldsymbol{\beta}_3 \\ &+ b_{i0} + b_{i1} \times (\text{year-2007})^2 + \boldsymbol{\varepsilon}_i\end{aligned} \quad (8)$$

where $\mathbf{y}_i$ is a vector that denotes the monthly product demand (the vector length is equal to the data quantity for product i); β_0, β_1, β_2, and β_3 denote the intercept, year, year-squared, and month for the fixed-effect term; and b_{i0} and b_{i1} denote the intercept and year-squared for the random-effect term. In Model (8), year was considered as a continuous variable with 2007 used as the baseline. Month was a categorical variable; therefore, the month term in Model (8) was a dummy variable. The dummy variable for month had 11 indicator variables with a value of 0 or 1, and the total product demand in January was used as the baseline. Expressing Equation (1) as Model (8), the fixed-effect explanatory variable $\mathbf{X}_i$ is a matrix comprising a column of 1's vector for the intercept, year, year-squared, and month covariates. Thus, the expression $\boldsymbol{\beta}=[\beta_0\ \beta_1\ \beta_2\ \boldsymbol{\beta}_3^T]^T$ is a 14 × 1 vector, where $\boldsymbol{\beta}_3$ is the coefficient of the dummy variable for the month covariate and has 11 elements. To account for the various product types, we chose the intercept and year-squared covariate as the random-effect explanatory variable, where the intercept was used to account for the average difference of demands between product types, and the year-squared covariate was used to consider the difference between product demands decreased or increased over time. The explanatory variable $\mathbf{Z}_i$ in the random-effect explanatory variable comprised the intercept and year-squared covariate, of which the coefficients are a 2 × 1 vector expressed as $\mathbf{b}_i=[b_{i0}\ b_{i1}]^T$. In Model (8), the year-squared covariate in the random-effect explanatory variable was also a part of the fixed-effect explanatory variable, and was used to account for the fact that the expectation of $\mathbf{b}_i$ was probably unequal to 0; thus, the assumption that $\mathbf{b}_i$ in (2) was equal to 0 was reasonable. The year-squared covariate was included to prevent the annual growth trend from being linear, which enabled the model to more accurately reflect the current situation. The year-squared covariate is crucial to practical operations. The year and year-squared covariates added into the fixed-effect explanatory variable facilitated establishing a grand model for the 20 product types. The year and year-squared covariates for the fixed effect indicated the average growth trend for the 20 product types, whereas the random effect reflected the specific annual growth trends for each product type. To forecast the monthly product demand for 2013, 2013 was used as the value for the year and year-squared covariates. Both covariates and the target month were input into the explanatory variable to form $\mathbf{X}_i^{new}$ and $\mathbf{Z}_i^{new}$. Subsequently, $\hat{\boldsymbol{\beta}}$ and $\hat{\mathbf{b}}_i$ in (7) were used to obtain the forecasted value $\hat{\mathbf{y}}_i$.

C. Other Forecasting Methods

Comparing forecasting methods is crucial in methodological studies [39 , 40 , 41 , 42 , 43]. The model proposed in this study was compared with commonly used statistical forecasting methods, beginning with the following linear model:

$$Y_j = \alpha_0 + \alpha_1 \times (\text{year}_j\text{-2007}) + \alpha_2 \times (\text{year}_j\text{-2007})^2 + \alpha_3 \times \text{month}_j + \delta_j \quad (9)$$

Table 3. Linear Mixed-Effect Model Versus the Linear Model.

Explanatory variable	Linear mixed-effect model			Linear model		
	Coefficient	Standard error	P value	Coefficient	Standard error	P value
The intercept term	39.46	320.14	.9019	174.54	294.07	.5529
(Year-2007)	800.55	133.52	.0000 ***	746.35	153.69	.0000 ***
(Year-2007)^2	-99.97	25.82	.0001 ***	-93.23	27.62	.0008 ***
February	206.41	283.03	.4660	171.14	327.19	.6010
March	736.88	281.57	.0090 **	716.23	325.51	.0280 *
April	753.30	281.56	.0076 **	762.56	325.50	.0193 *
May	536.51	280.89	.0564 -	504.53	324.70	.1205
June	253.56	281.62	.3681	218.06	325.53	.5031
July	591.73	271.46	.0295 *	556.53	313.77	.0764 -
August	91.35	271.48	.7366	56.21	313.77	.8579
September	711.75	271.46	.0088 **	664.40	313.77	.0344 *
October	297.69	271.05	.2723	255.00	313.28	.4158
November	473.91	272.52	.0823 -	432.47	314.94	.1699
December	360.30	270.62	.1833	308.34	312.71	.3243

" - ": p < .1; " * ": p < .05; " ** ": p < .01; " * ": p < .001.**

where α_0, α_1, α_2, and α_3 are regression coefficients and α_3 denotes the coefficient of the dummy variable for the month covariate, and δ_j is the error term. Model (9) (i.e., the linear model) includes only the fixed-effect term in Model (8) (i.e., the mixed-effect model); therefore, Model (9) was compared with Model (8) to examine the differences when the random-effect term is present or absent in the model. A total of 1295 observations of monthly product demand (Y_j, $j = 1,...,1295$) were used to estimate the coefficients in Model (9) and the significance of the coefficients with P values. In the Results section, Models (8) and (9) are compared regarding forecast accuracy and the P values.

Next, the model proposed in this study was compared with the exponential smoothing method, in which the product demand observation values Y_t's and its predictive values F_t's were used to obtain the predictive values for the subsequent period by calculating a weighted mean. The forecast formula is as follows:

$$F_{t+1} = \alpha Y_t + (1 - \alpha) F_t$$

where α is the weighted coefficient. To accurately forecast the monthly product demand in this case, we adjusted the exponential smoothing method to account for two influential factors (i.e., month and product type). The data were divided into 20 data sets according to each product type, and each data set was divided into 12 subsets (one for each month). For each product type, no more than six observations from each month in the historical data were used. The pre-2012 monthly product demand data were used to forecast the product demand for the corresponding months in 2013. The weighed coefficient was $\alpha = \frac{1}{2(N+1)}$, where N is the number of observations for a month ($N \le 6$).

Finally, the model proposed in this study was compared with a seasonal time-series model; specifically, the autoregressive moving average model ($ARMA(2,2)_{12}$), which was considered to be a suitable model because the data were not nonstationary time-series data. The mathematical model for ARMA $(p,q)_s$ is expressed as follows:

$$(1 - \sum_{i=1}^{p} \phi_i B^{s \times i}) Y_t = (1 + \sum_{i=1}^{q} \theta_i B^{s \times i}) \xi_t$$

where ϕ_i is the ith order autoregressive process coefficient, B is a backward shift operator, θ_i is the ith order moving-average process coefficient, ξ_t is a normally distributed confounding term, and s is a seasonal parameter. Longitudinal data were collected for each of the 20 product types. A time-series model was established for each of the 20 product types. In this case, the month was regarded as a crucial influential factor for forecasting and thus the seasonal parameter s was set to 12, which indicates the existence of correlations in the data for every 12 month. The samples were categorized by product type, yielding an average of 64 samples for each type of product. The parameters p and q were determined based on the characteristics of an autocorrelation function, a partial autocorrelation function, and an extended autocorrelation function (p = 2 and q = 2). Finally, the $ARMA(2,2)_{12}$ model was used to forecast the product demand for each product type.

Table 4. Error Indicators for the Four Forecasting Methods.

	MAE		MAPE		RMSE	
	M	*SD*	*M*	*SD*	*M*	*SD*
Linear mixed-effect model	1,412.71	1,500.04	1.52%	1.50%	1,849.42	1,919.86
Linear model	1,828.96	2,091.93	3.77%	6.00%	2,259.99	2,712.69
$ARMA(2,2)_{12}$	1,509.22	1,938.23	1.92%	2.04%	1,942.48	2,533.25
Exponential smoothing method	1,565.54	1,547.88	2.01%	1.77%	2,003.87	2,193.16

D. Results

In this study, mean of absolute error (MAE), mean of absolute percent error (MAPE), and root-mean-square error (RMSE) were used as error indicators. The definitions for these error indicators are provided as follows:

$$MAE = n^{-1}\sum_{t=1}^{n} |F_t - Y_t|$$

$$MAPE = 100n^{-1}\sum_{t=1}^{n} \left|\frac{F_t - Y_t}{Y_t}\right|$$

$$RMSE = \left(n^{-1}\sum_{t=1}^{n} (F_t - Y_t)^2\right)^{0.5}$$

where n denotes the number of months to be forecasted (n = 12 in this case), Y_t represents the true product demand for month t of 2013, and F_t is the forecasted product demand for month t. The fixed-effect term in the linear model was compared with that in the linear mixed-effect model. As shown in Table 3, the absolute values of the coefficients for the explanatory variables in the linear mixed-effect model containing the random-effect term are greater (i.e., further from 0) than all of those in the linear model except for April. In addition, the standard errors and P values for all of the explanatory variables in the linear mixed-effect model are smaller than those in the linear model. Regarding the linear fixed-effect model, compared with January in a given year, the product demand was significantly greater in May and November (P value < 0.1), in July (P value < 0.05), and in March, April, and September (P value < 0.01). Compared with the linear fixed-effect model, the linear model yielded less significant results. The linear model is suitable for data containing mutually independent observation values. In this case, the observation values for product demand were correlated over time, thereby violating the assumption of the linear model. Therefore, the standard errors and P values for the linear model (Table 3) are not valid estimates, whereas those for the linear mixed-effect model are more reliable. Table 4 shows the error indicators for the four forecasting methods. Because this case involved three error indicators for each of the 20 product types, Table 4 presents the mean and standard deviation of the three error indicators. As shown in Table 4, the means and standard deviations of MAE, MAPE, and RMSE for the linear mixed-effect model are lower than those for the linear, ARMA, and exponential smoothing models, indicating that, in this case, the linear mixed-effect model is superior to the other three models. Regarding the model comparison (Table 5), the predictive values obtained through using the linear model to process the correlated data are unbiased [23]. However, the linear mixed-effect model (8) contains the random-effect term, whereas the linear model (9) does not. Therefore, in Model (8), the intercept and year-squared terms differ according to the product type, and thus the corresponding intercept values and coefficients differ based on the product type. In Model (9), the covariate of product type is not included in the explanatory variables, which generates identical predictive values for various product types in the same years and months. Thus, this model cannot predict the product demand for the individual product types, rendering its forecasting effectiveness inferior to that of Model (8). Regarding the exponential smoothing method, we considered product type and month as crucial influential factors, which were used as the basis for dividing the data into 240 data sets. For each product type, the pre-2012 monthly data were used to forecast the monthly product demand for 2013. In this manner, the exponential smoothing method was applied 12 times for each of the 20 product types. In addition, less than six observations from the historical data were used in the exponential smoothing method (for a given month, there were at most 6 sets of data from 2007 to 2012); consequently, the risk of inferential error was high because only a few observations were involved in the prediction. Regarding the seasonal time-series model $ARMA(2,2)_{12}$, we considered product type as a crucial influential factor and divided the data into 20 data sets according to product type. For each product type, 64 observations were used on average. The $ARMA(2,2)_{12}$ model was used to forecast the product demand for each product type by considering the correlation between the data for every 12 month. For both the exponential smoothing method and the $ARMA(2,2)_{12}$ model, the data were divided into subsets according to the product type and then used to estimate the monthly effect of each product type. Accordingly, although such procedure could consider the various monthly effects for various product types and the interaction between product type and month, it reduces the number of data observations involved in the prediction. In the linear mixed-effect model, 1295 data observations were used to estimate the random effect for each product type. The number of data observations used in the linear mixed-effect model was considerably more than that used in the exponential smoothing and time-series models, which could explain

Table 5. Comparison of the Four Models.

	Number of models	Number of samples	Consideration for the effect of product type	Consideration for the effect of month	Consideration for the interaction effect of product type and month
Linear mixed-effect model	1	1,295	〇	〇	※1
Linear model	1	1,295		〇	
ARIMA(2,2)	20	≤72	〇	〇	〇
Exponential smoothing method	240	≤6	〇	〇	〇

※1 This effect is nonsignificant

why the linear mixed-effect model produced lower forecast errors. In addition, in Model (8), the random effect of the interaction term for month and year-squared term was considered and the likelihood ratio test was employed to examine whether this term is significant to this model. The results showed that only the random effects of the intercept and year-squared terms were significant, and the random effect of the month term did not significantly enhances its explanatory power for the data. Therefore, the random effect of the interaction term was not included in Model (8).

V. DISCUSSION

In summary, when applying the linear mixed-effect model, all of the historical data were used in one model to predict the monthly product demand for each product type, and to avoid problems resulting from dividing the data into smaller data sets. In this case study, using the linear mixed-effect model enables manufacturers who adopt the MTS production strategy to predict the amount of inventory they should stock. Furthermore, the model is more effective in forecasting product demand than is the time-series, exponential smoothing, and linear models.

Similar to the linear model, the linear mixed-effect model is typically used to examine the relationship between explanatory and research variables. Unlike the linear model, which assumes the observation values to be mutually independent, the linear mixed-effect model is suitable for examining correlated data. Because the data pertaining to business operations are generally correlated over time, the linear model is limited in applicability. By contrast, the linear mixed-effect model was initially developed to handle correlated data. Other methods such as the time-series and exponential smoothing methods formulate the correlation between observation values as parameters, and then estimate the parameters by data and forecast the observations by the estimates. When the time-series and exponential smoothing models were first developed, these methods were not aimed at analyzing the relationship between explanatory and dependent variables. Wang [19] proposed an exponential smoothing method that included explanatory variables and can be used to explore the association of research variable. Because this method is a relatively new development, most of statistical software packages have not yet incorporated related functions, and thus this method has not been widely used. By contrast, the linear mixed-effect model was developed more than 30 years ago, and related functions have been included in various statistical software packages.

Using linear mixed-effect, time-series, and linear models to forecast product demand can yield negative predictive values. This phenomenon occurs when the linear mixed-effect model is used because $\boldsymbol{\varepsilon}_i$ in (2) is assumed to be normally distributed and the link function is an identity function. Negative values are usually obtained from historical data where product demand is zero or very low. To prevent this, predictive value was truncated at 0 (i.e., $F_t = \max(\hat{Y}_t, 0)$, where $\hat{Y}_t$ denotes a predictive value derived from any method, and F_t denotes an actual predictive value obtained from any prediction method). In other words, if $\hat{Y}_t > 0$, then $F_t = \hat{Y}_t$; if $\hat{Y}_t \le 0$, then $F_t = 0$. Some link functions in generalized linear mixed-effect model can deal with the case where dependent variable is restricted to $\hat{Y}_t \ge 0$ [44]. However, the prediction intervals for the random-effects in linear mixed-effect model are well developed [45, 46, 47, 48, 49]. It is useful to apply the prediction intervals in business operations for knowing whether the random-effect exists.

Implementing an MTS production strategy can enhance the competitive advantages of a manufacturer, enabling the manufacturer to rapidly satisfy product demand, thereby reducing internal and external transaction costs for handling orders. Employing this strategy also enables high batch centralized production and thus can reduce production costs and assist manufacturers in negotiating with material suppliers about the cost of materials. Because this approach enables short delivery times, customer satisfaction can be improved, thus attracting potential customers who need products immediately. Consequently, market share can be increased. MTS production also enhances the usage rate of production equipment. Companies that adopt an MTS strategy require an accurate forecasting method to realize these advantages. This study proposed an accurate forecasting method for determining the stock levels a company should determine for adopting the MTS production strategy, a topic that has seldom been discussed in studies on MTS production.

Using an MTS production strategy involves the potential risk of increasing inventory costs. Therefore, future studies should adequately apply the strengths of the linear mixed-effect model (e.g., accurately forecasting demand for multiple product types in one go) when forecasting. Future studies should consider investigating whether the forecasting intervals of the linear mixed-effect model can be coupled with various inventory strategies to assist manufacturers with adopting the MTS production strategy in order to develop an optimal business operation model in terms of optimal inventory time points and minimal inventory costs. In addition, to remain competitive, companies should enhance their organizational capability for elevating the threshold that enables competitors to develop similar operating models. Future studies are also recommended to explore the benefits that the MTS production strategy involving a linear mixed-effect model brings to the various departments of an enterprise and the effects of such strategy on customer satisfaction and loyalty.

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