ELECTROSPINNING OF CHITOSAN/POLY (VINYL ALCOHOL) NANOFIBROUS MEMBRANES AS AN ALTERNATIVE WOUND DRESSING MATERIAL

[1]HARINI SOSIATI, [2]RAFI IMAM AR-RASYID, [3]PARAMA AJI DARMAWAN, [4]KRISDIYANTO

[1,2,3,4]Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta,
Jl. Brawijaya, Kasihan, Bantul, Yogyakarta 55183, Indonesia
E-mail: [1]hsosiati@ft.umy.ac.id, [2]rafiimamarrasyid@gmail.com, [3]paramagood@gmail.com, [4]krisdiyanto@umy.ac.id

Abstract - A study of the influence of CS concentrations on the tensile properties corresponding to the fiber morphology formed in CS/PVA membranes is this research focus. The ability of the developed membranes for an alternative wound dressing material is also studied. The CS/PVA membranes were prepared using chitosan (CS) solution with different concentrations of (1, 3, 5, and 7 wt. %) combined with 10 wt. % poly (vinyl alcohol) (PVA) and a CS/PVA ratio of 5/95 by electro spinning method. The membranes with an optimized CS concentration of 3% and different CS/PVA ratios of 10/90, 15/85, and 20/80 were also studied. The membrane with 3 % CS concentration showed an optimum tensile strength (5.62 ± 0.47 MPa) with a CS/PVA ratio of 5:95. The improvement of the CS/PVA ratio increased the tensile strength and modulus of the membranes, which reached a maximum value (7.68 ± 1.94 MPa) at a CS/PVA ratio of 20:80, leading to a high density of tight bonds between the fibers. A simulation by finite element method (FEM) on the tensile properties of the CS/PVA membrane has shown that the membrane can be used as an alternative wound dressing material.

Keywords - Chitosan, PVA, Nanofibrous Membrane, Tensile Properties, Wound Dressing Material

I. INTRODUCTION

In the design of materials for some industrial applications, the achievement of the mechanical properties of the material, which is matching with the production target is one of the required product specifications. For example, the tensile properties of nanofiber membranes that are useful in certain applications such as food packaging and biomedical, should at least have a high strength and elasticity of the products. The rapid growth of nanofiber technology is the result of the nanotechnology revolution, which has made it possible to produce membranes from polymers. In this case, electro spinning is a simple method and useful for making polymer nanofibers. The simplicity of process technology in producing fiber in size from nanometer to sub-micro with a non-woven has made the preferred method. Related to the product of nanofiber membranes, a natural polymer of chitosan (CS) and a synthetic polymer of poly (vinyl alcohol) (PVA) were used as base materials in the current study. It is well known that chitosan produced from shrimp shell waste [1–3], is abundantly available in the earth, especially in the regions located near the sea. The effort to make efficient use of the waste is one of the environmental awareness.

In addition, chitosan is very useful in biomedical [4, 5] and food [6, 7] industries due to its advantageous characteristics such as biocompatible, non-toxic, antimicrobial, and biodegradable [8]. On the other hand, PVA is a semi-crystalline synthetic polymer and has almost the same as chitosan, except water solubility. Chitosan is insoluble in water, but soluble in acetic acid (CH_3COOH), whereas PVA, is completely water-soluble, insoluble in the organic solvents and slightly soluble in alcohol [9, 10]. Therefore, a combination of CS and PVA is potentially also used for biomedical and food packaging applications. The studies of CS combined with PVA by electro spinning have been performed to address the characterization of the CS/PVA membrane properties and the use for wound dressing and wound healing [11–14]. The nanofiber membrane of the CS/PVA blend is better in mechanical properties than the neat PVA membrane and may be used in soft tissue engineering. The electrospun membranes made up of 1% chitosan and 10% PVA solutions combined with some different ratios of PVA/CS 80/20, 70/30, 60/40, and 50/50 were potential for wound care. The healing of the wound using the PVA/CS membrane was approximately 40% faster than the open wound [11]. PVA/CS nanofiber membrane tends to be an excellent material for wound dressing, it does not irritate the skin, although it has been in contact with the skin for a long duration (more than a few months) [12].

One % CS and 8% PVA solutions blended at the ratio of 50/50 resulted in a fiber structure closed to the natural tissues, indicating that it is capable of wound healing due to infection [13]. The CS/PVA nanofiber membrane at CS/PVA ratio of 25/75 and an average fiber of about 289 nm was very decisive in healing a diabetic wound on the mice [14]. However, few studies discussed the characterization of the tensile properties of CS/PVA nanofibrous membranes and the use of measurement properties for stress analysis. For wound dressing application, the mechanical property is one of the significant properties of the membrane. The membrane should have high strength,

sufficient modulus elasticity, and high strain, such as the properties of the natural tissue. When membranes are used, membranes may accept tensile loads. For example, if the membrane is used to cover the injury that occurred to the elbow or knee, and then the hand or legs are moved from a straight to a bent position, the membranes will receive a tensile load. It is, therefore, necessary to make the data of the tensile properties of the membranes and to perform the characterization and analysis. The current study discussed the tensile properties of the CS/PVA membranes affecting by the CS concentrations associated with the fiber morphology formed in the nanofibrous membranes. Besides, the capability of the membranes for alternative wound dressing material based on the data on tensile properties data was studied by a simulation using the finite element method (FEM) supported by Abaqus Simulia software. This analysis is required as the first step of confirmation before the membrane is produced for a commercial product.

II. DETAILS EXPERIMENTAL

2.1. Materials and Preparation of CS/PVA blend

Chitosan (CS) micro-powder and acetic acid (glacial, 99 – 100%) were obtained from Sigma-Aldrich and Merck, respectively. PVA (Gohsenol, Mw: 22,000 g/mol) was purchased from CV. Multi Kimia, Yogyakarta, Indonesia. Chitosan (CS) solutions with varying concentrations of 1, 3, 5, and 7 % (w/w) were prepared by dissolving chitosan micro-powder in the 2% (w/w) acetic acid solution. The dilution of the acetic acid solution was carried out at room temperature by stirring the solution at 200 rpm for 15 minutes. Subsequently, the dissolution of chitosan powder in the acetic acid solution was performed by heating the chitosan solution at around 80°C and magnetic stirring at 200 rpm for about 45 minutes and then cooling down to room temperature. In addition, the PVA solution was ready at a concentration of 10% (w/w).

2.2. Manufacture of the CS/PVA nanofiber membranes

The mixture of CS and PVA solutions used for the spinning solution was prepared in two types of CS/PVA blends, namely (1) CS/PVA blends at a CS/PVA ratio of 5/95 with 1, 3, 5 and 7 % CS concentrations, and (2) CS/PVA blends at 3% CS concentration with CS/PVA ratios of 5/95, 10/90, 15/85 and 20/80. The viscosity of all CS/PVA blends was measured with a Brookfield viscometer. All CS/PVA blends were inserted into the syringe in the electro spinning machine for the production of CS/PVA nanofiber membranes. The electro spinning process ran at an applied voltage of 18 kV, a fixed distance between the tip and the collector plate of 16.5 cm, a needle diameter of 0.6 mm, and a feed rate of ~0.5 ml/h.

2.3. Characterization

Scanning electron microscopy (SEM, Hitachi 3500-SU) was used to characterize the fiber morphologies of the produced membranes. The fiber diameter measurement was carried out by measuring at least 100 fibers on the SEM image using the ImageJ open-source software. The tensile test for all the membranes was carried out according to ASTM D-882, using a testing machine (Zwick Z0.5 Germany) at a crosshead speed of 10 mm/min and a gauge length of 20 mm. Seven membrane specimens with an average thickness of approximately 40 µm were prepared for each variation, in which the thickness was measured under an optical microscope (Olympus SZ 61).

2.4. Simulation

The simulation used the tensile properties of the second round of CS/PVA blending membranes. The membrane size of this simulation was modeled on the basis of a large-scale commercial band-aid: i.e., 60 mm in length and 30 mm in width. The use of the membrane in this research is to cover the wound near the elbow. When the position of the membrane moves from a straight position to be a bent position, the displacement will be occurred. This process is simulated and analyzed using the Abaqus Simulia software-supported FEM.

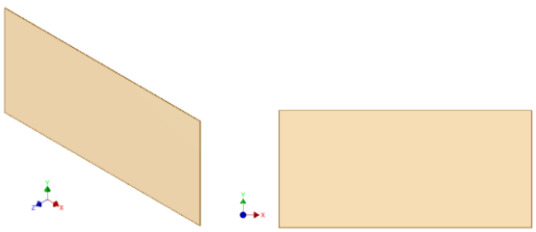

Fig.1. Geometric of the membrane.

In this simulation, the geometric of the membrane was firstly made (Fig.1). The geometric was then imported to the finite element-based software and given a force until the value of von misses is equivalent to the tensile strength of the used membrane.

III. RESULTS AND DISCUSSION

3.1. Optimization of CS Concentration

In the study of CS/PVA blend by electro spinning, the use of CS concentrations is different from each other. The CS concentration used in this study was optimized based on the result of

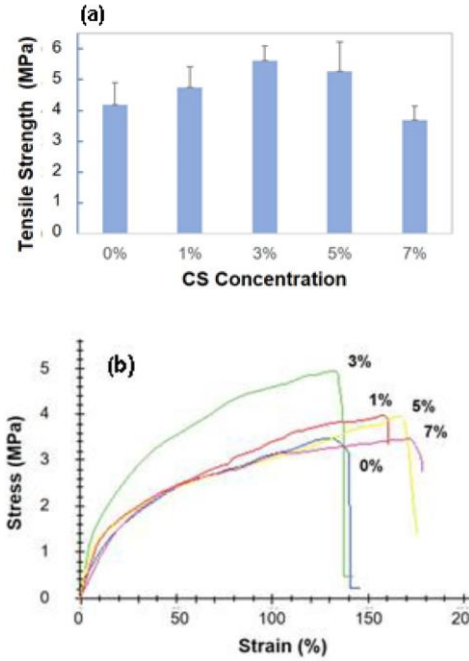

Fig.2. The tensile properties of CS/PVA nanofiber membrane at CS/PVA ratio of 5/95. (a) tensile strength vs CS concentration, and (b) stress-strain curve.

The tensile properties (Fig.2). In this case, the CS/PVA membrane with a concentration of 3% CS shows an optimum tensile strength value, whereas its elongation is almost the same as the elongation of the neat PVA. The elongation at break ranging from 100% to 150% seemed to be a part of the range of natural tissue properties. As a result, 3% of CS concentration was used to better classify CS/PVA mixtures by varying CS/PVA ratios. A study of the CS/PVA nanofibrous membrane with 3% CS concentration has achieved an optimum value of CS/PVA ratio at 50/50 based on better fiber structure formulation compared to other ratios [15]. Another research study varied the CS concentration from 0% to 3% to understand its effects on the formation of fiber during the electro spinning process. This research confirmed that the CS concentration of less than 2% and higher than 3% made the solution is not spinnable due to excessive viscosity of the solution [16- 17].

3.2. FTIR Analysis

The chemical structure of pure PVA, chitosan, and CS/PVA has different characteristics (Fig.3). The FTIR spectrum of pure PVA exhibits the main positions related to –OH stretching (3364 cm^{-1}), –CH stretching (2931 cm^{-1}), stretching vibration of C=O groups (1735 cm^{-1}), –CH bending (1427 cm^{-1}), –C–O– stretching (1087 cm^{-1}) [18, 19]. In the spectrum of pure chitosan, the peaks at 3425 cm^{-1} and 2900 cm^{-1} are correspond to –OH and $–NH_2$ stretching groups and –CH stretching vibrations [18, 20]. The absorption bands identified at 1643 cm^{-1}, 1580 cm^{-1} and 1087 cm^{-1} are related to amide I, II, and a weak amide III, respectively [21], while those positioned at 1087 cm^{-1} and 887 cm^{-1} are associated with –C–O– stretching vibration [18]. The broad peak corresponding to –OH stretching at approximately 3400 cm^{-1} is present in all spectra, which sifts to lower wave number as PVA content increases [19]. In the CS/PVA spectra, the coexistence of the functional groups of the C=O groups, amide I, and II is represented in the CS/PVA (20/80) spectrum: i.e., at the positions of 1728 cm^{-1}, 1651 cm^{-1}, and 1566 cm^{-1}, respectively. Such results showed strong compatibility between CS and PVA in the CS/PVA nanofiber membranes. In the event that they are incompatible, the spectrum will show to be similar to the pure component one [19].

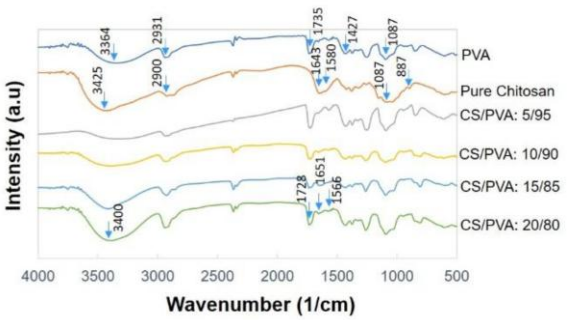

Fig.3. FTIR spectra of pure PVA and chitosan, and CS/PVA nanofibrous membranes at 3% CS concentration with various CS/PVA ratios.

3.3. Fiber morphology

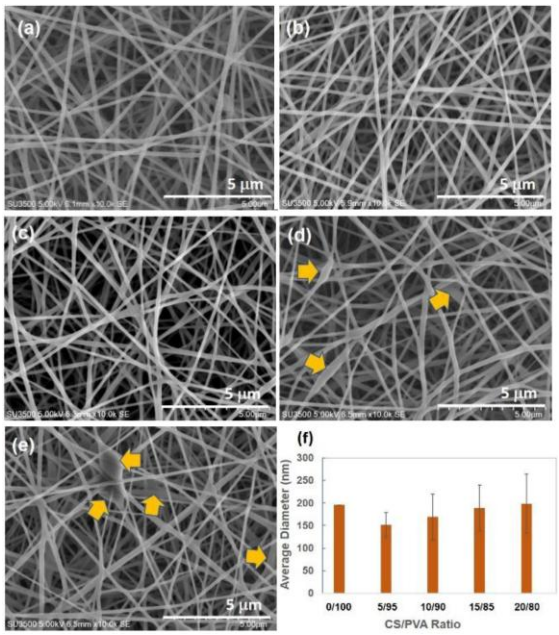

Fig.4. SEM images of nanofibrous membranes of CS/PVA blend with various CS/PVA ratios; 0/100 (a), 5/95 (b), 10/90 (c), 15/85 (d), 20/80 (e) showing the formation of beads in (d) and (e) (see arrows).

The fiber morphologies formed in all membrane specimens reveal straight-oriented fibers with a uniform size distribution, particularly at SC/PVA

ratio of 0/100 (neat-PVA) (Fig.4a) and 5/95 (Fig.4b). The higher the CS content, the larger the average fiber diameter (Fig.4f), which corresponds to the viscosity of CS-PVA spinning solutions (Table 1), which increases by increasing the CS concentration. The average fiber diameter of all CS/PVA fibrous membranes is in the range of 100 - 200 nm, which is proportional to a previous result [15]. Enhancing the viscosity of the spinning solution is not only providing an impact on the fiber diameter but also the formation of beads as fiber-defect, that has gradually been produced at CS/PVA ratio of more than 5/95 (Fig. 4d and 4e, see arrows). In this case, viscosity is a function of intermolecular interaction in the polymer structure. Thus, the viscosity of the solution has a significant impact on

Specimen at CS/PVA	Viscosity (cP)	Average fiber diameter (nm)
0/100	340	196
5/95	465	151
10/90	554	169
15/85	606	195
20/80	809	198

Table 1: Viscosity of the spinning solution of CS-PVA

the formation of fiber other than surface tension and electrical conductivity [22]. However, the beads formed in these membranes do not obstruct the cross linking of the fiber. It should be noted, therefore, that 3% of CS concentration yielded the appropriate viscosity of the solution resulting in good electro-spinnability.

3.4. Tensile properties related to fiber morphologies

The fiber morphology in terms of fiber structure affects the tensile properties of the nanofibrous membranes. As far as our experience in the manufacture and characterization of the electro spun membranes is concerned, the fiber crosslink has positively played a crucial role in the tensile properties of the membranes. The higher the volume fraction of crosslink between fibers in the membrane, was formed, the higher the tensile strength of the membrane. Based on the present result (Fig.5a), the addition of chitosan gradually improved the tensile strength of the CS/PVA membranes, but the elongation varies (Fig.5b). The earlier result [15], which used around 2.5% CS concentration and different CS/PVA ratios showed comparable tensile strength (6.13 ± 0.72 MPa), significantly higher tensile modulus (94.2 ± 10.2 MPa) and lower elongation at break (14.13 ± 1.25%) at CS/PVA ratio of 15/85 compared to the present results. These measures were higher than the properties of CS/PVA membranes at CS/PVA ratios of 25/75 and 30/70, explaining that an increase of chitosan content yielded unfavorable tensile properties, especially for wound dressing material due to too high modulus elasticity. Compared to another study [21], without the addition of chemical cross linking (tetraethyl ortho silicate/TEOS), these present results showed higher specifically in the tensile strength, but lower in the elongation at break. Besides, these tensile properties are also better than the other [23], although the chemical cross linking of glutaraldehyde (GA) has been used. In principle, the nanofibrous membrane with very high modulus elasticity is not applicable for wound dressing material. The tensile properties of these nanofiber membranes are used for the simulation analysis using Abaqus Simulia software in the next paragraph to ensure whether the produced membranes would be applicable for an alternative wound dressing material or not. Based on the result in Fig. 5a, the CS/PVA membrane with a CS/PVA ratio of 20/80 reaches the highest tensile strength (7.68 ± 1.94 MPa). This property was used for the following simulation.

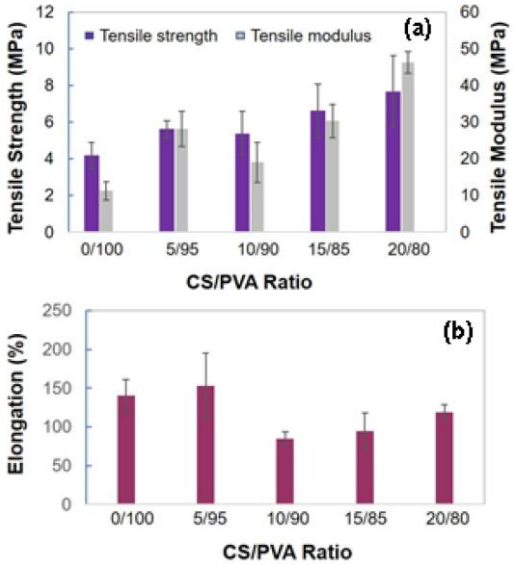

Fig.5. Tensile strength and modulus vs CS/PVA ratio (a) and elongation vs CS/PVA ratio (b).

3.5. A simulation result applied to the CS/PVA nanofiber membrane

The CS/PVA membrane with a CS/PVA ratio of 20/80 is selected for this simulation due to its highest tensile strength. The CS/PVA membrane application model in Fig. 6. displays the length of the membrane at a straight position of 60 mm. However, at a bent position, the range extends to be 65 mm, explaining that there is a displacement of about 5 mm toward x-direction. In this case, the trial and error were performed to determine the thickness of the membrane. The membranes with the dimension of 60 mm length, 30 mm width and various thicknesses from 40 μm to higher than 100 μm have been tried for modeling from a straight to the bent position. The results showed that the membrane had failed due to a thickness of less than 110 μm. Nevertheless, at an average thickness of 110 μm, when determined by an

optical microscope (Fig.7), the membrane worked excellently with a displacement of about 5 mm, as depicted in Fig.6. The membrane with a dimension of 60 (l) x 30 (w) x 0.11 (t) is therefore used for stress analysis.

(a)

(b)

Fig.6. An application model of the CS/PVA membrane to cover the wound in a straight position (a) and in a bent position in which the displacement occurred.

The stress analysis of the membrane performed using Abaqus Simulia software shows the geometrically based-simulation result (Fig.8) and von misses stress of the membranes when the elbow of a hand is folded. It is shown that the maximum von misses of the membrane is about 7.67 MPa, which is equivalent to the maximum tensile strength, and the displacement demonstrates a maximum value of around 5 mm, which corresponds to the actual measurement exhibited in Fig.6b.

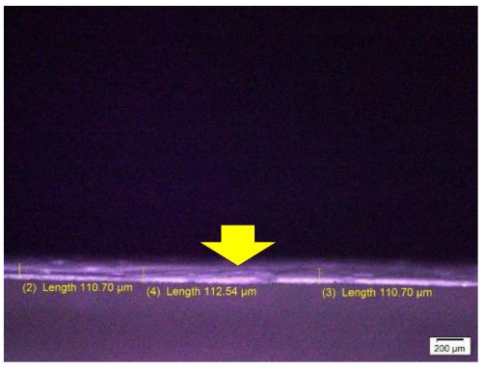

Fig.7. An optical micrograph of a cross-section of the membrane showing an average thickness.

This result suggested that the CS/PVA membrane with a CS/PVA ratio of 20/80 would be useful for an alternative wound dressing material by designing a dimension of 60 mm in length, 30 mm in width and a minimum thickness of 0.11 mm (110 m) which provides a 5 mm displacement of the membrane. However, a significant improvement in the tensile properties of the nanofibrous membrane is required in the next research.

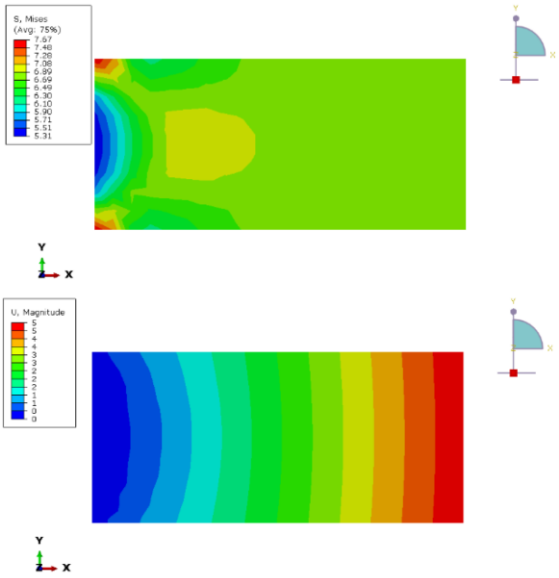

Fig.8. Abaqus Simulia simulation result.

IV. CONCLUSION

The electrospinning technique has successfully manufactured the CS/PVA nanofibrous membranes. The influence of the variation of CS concentrations and CS/PVA ratio on the tensile properties of CS/PVA membranes has resulted in some significant points. Increased CS concentration increases the tensile strength of the CS/PVA membrane with a CS/PVA ratio of 5/95, resulting in an optimum CS concentration of 3% with a tensile strength of 5.62 ± 0.47 MPa. Various CS/PVA ratios at 3% CS concentration showed a gradual increase in the tensile strength and modulus in which the maximum values reached by the membrane with CS/PVA ratio of 20/80 were 7.68 ± 1.94 MPa and 46.3 ± 2.89 MPa, respectively, and the elongation at break of 118.65 ± 10 %. Based on the simulation result using FEM supported by Abaqus Simulia software, the CS/PVA membrane with those properties is recommended as a wound dressing material by designing a dimension of 60 mm in length, 30 mm in width, and a minimum thickness of 0.11 mm (110 µm).

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EFFECT OF 45-DEGREE CAPILLARY PIPE SLOPE ON HORIZONTAL AND FLUID VISCOSITY ON THE WATER-AIR TWO-PHASE FLOW PRESSURE GRADIENT

[1]SUKAMTA, [2]MUHAMMAD ROCKY PRATAMA, [3]SUDARJA

[1,2,3]Department of Mechanical Engineering, Faculty of Engineering, Universities Muhammadiyah Yogyakarta, Jalan Lingkar Selatan, Tamantirto, Kasihan, Bantul, Daerah Istimewa Yogyakarta, Indonesia, 55183
E-mail: [1]sukamta@umy.ac.id, [2]Rockypratama6@gmail.com, [3]sudarja@umy.ac.id

Abstract - Two-phase flow is a stream of the simplest multiphase flow. The two-phase flow consists of 3 states, namely liquid-solid, gas-liquid and gas-solid. Basic characteristics of two-phase flow include flow patterns and flow pattern maps, vacuum fractions, and pressure gradients. This research discusses the investigation of pressure gradients in two-phase flow. Pressure gradients are used in the piping industry to determine the pressure of the fluid in the flow in the pipe. This research was conducted in the test section in the form of a glass pipe that has a diameter of 1.6 mm with a slope angle of 450 towards the horizontal position. The liquid used is a mixture of water and glycerin with presentations of 40%, 50%, 60%, and 70%. This research was conducted to determine the effect of superficial gas (JG), liquid (JL) velocity and the effect of viscosity on pressure gradients. An MPX pressure transducer was used to detect pressure differences or pressure drops in the flow connected to the computer. The results showed that the pressure gradient is influenced by the velocity of the liquid, gas, and viscosity. The influence of JL in the range of 0.091; 0.149; 0.232; 0.539; 0.7; 0.879, and 2.297 m / s by varying JG (0 - 66.3) m / s and JG in the range of 0.025; 0.116; 0.423; 1.941; 7; 9.62 and 50 m / s by varying JL (0.033 - 4.935) m / s experienced an increase in the pressure gradient with each increase in the value of the JG and JL varied. Viscosity also affects the pressure gradient, from the results of research data on GL 40%, 50%, 60%, and 70% by varying JG = 22,6 m / s and JL = 0,879 m / s. This shows that as the viscosity of the liquid increases, the resulting pressure gradient will increase.

Keyword - Capillary Pipe, Pressure Gradient, Slope, Superficial Velocity, Viscosity

I. INTRODUCTION

The two-phase flow examines the basic parameters, with a test investigation carried out using a mixture of water-air and glycerin with the simplest multi-phase flow method. Glycerin in fluids causes the nature of the fluid to change in viscosity, so the two-phase flow research is carried out by varying the liquid mixture to increase its viscosity. The pressure gradient is a decrease in pressure per unit length. Pressure gradients are widely used in the piping industry which is used to determine differences in fluid pressure in pipes. The pipes used in the research of various two-phase flow, including nano-sized pipelines (nanochannels), micro (microchannel), mini (mini channel), normal (normal channel), large pipe channels (large channel) and on this research was carried out by measuring the viscosity by using the superficial gas velocity (JG) and superficial liquid velocity (JL) varies.

The pressure gradient is obtained by processing data obtained from a single-board microcontroller, the MPX System Pressure Transducer. This method is able to provide vast amounts of data in a short and accurate period of time. There was a previous study investigating the pressure gradient conducted by Fukano et al. ([1] which says that viscosity affects the pressure gradient while the slope angle of the pipe has no effect on the pressure gradient. Similar research was carried out by Dutkowski [2] who examined the pressure gradient on two-phase flow characteristics. Research on two-phase flow has also been done by Triplett et al.[3] who focused on vacuum fraction and pressure gradients in micro pipes. The size of micro pipes with a diameter of 1.1 (mm) and 1.45 (mm) with the superficial gas velocity of 0.02-80 (m / s) and superficial liquid of 0.02-8 (m / s). The test used a mixture of air-water. The correlation used produces significant data for the reduced friction pressure from homogeneous flow due to the annular flow obtained. Hassan et al. [4] investigated experimentally about the decrease in two-phase flow pressure in millimeters in miniature pipes. In this experiment, three models were used including homogeneous, Friedel models and Chisholm models. Pressure gradients due to friction of two-phase flow carried out at pipe diameters of 3 mm, 1 mm and 0.8 mm show different results between the results of the test experiments with the correlation of previous tests. Bubbly, intermittent, churn and annular flow is the flow that is influenced by surface tension and flows with the effect of inertia. Awaludin et al.[5] conducted a study on the analysis of two-phase air-water flow at a 45º bend in a horizontal position upward with a pipe diameter of 26.64 mm. The results show that there are differences in experimental and theoretical pressure drop due to theoretical calculations using several assumptions that do not take into account field conditions such as pipe connections, pipe bends, and other flow losses. This study found that the decrease in two-phase flow through 45º turns decreased with increasing gas volume fraction (β). While Barreto et al. [6] conducted research with an air-water adiabatic fluid in a circular pipe with an upward diameter of 1.2 mm.

In this study, the superficial gas velocity (JG) = 0.1-34.8 m / s and the superficial liquid speed (JL) = 0.1-3.5 m / s. Correlation in small tubes with air-water shows the best prediction of pressure drop data on annular pattern with a superficial gas velocity of more than 18.6 m/s. Abubakar et al.[7] said that the pressure gradient will increase with increasing viscosity of the mixture. In a one-phase flow, the pressure drop is only affected by the Reynold number which is a function of the viscosity, the specific gravity of the fluid and the diameter of the pipe. But the multiphase flow is not only influenced by the Reynold number but also influenced by the phases that are mixed in it.

The superficial gas/water velocity and viscosity of the liquid in addition to influencing the pressure gradient study also affect the two-phase flow pattern research, such as the research conducted by Sukamta et al. [8] which used mini glass with a diameter of 1.6 mm and a length of 130 mm with a slope of 30º. The fluid used is air-water + glycerin with a concentration of 40%, 50%, 60%, and 70%. Liquid superficial velocity JL = 0.033 - 4.935 m / s and superficial velocity JG = 0.025 = 66.3 m / s. High-speed cameras are used to visualize flow patterns. The results can be concluded that the superficial gas/water and liquid viscosity significantly influence the flow pattern. Two-phase research of the pressure-gas-liquid pressure gradient in a mini-channel was conducted by Sudarja et al. [9], the test portion is a transparent circular channel with a diameter of 1.6 mm. The working fluids are air and water with superficial gas and liquid speeds, respectively in the range of 0.025-66,300 m/s and 0.033-4,935 m/s. Pressure gradients are obtained using the respective pressure transducer. The results found that superficial gas and liquid velocity affects proportionally to the pressure gradient, while it increases by increasing JG and JL. Previous research was also carried out by Sudarja et al. [10] for compressive gradients in a two-phase flow of air mixed with 20% water and glaciers in a 1.6 mm diameter horizontal position pipe. The gas superficial velocity and the range 0.025-66.3 (m/s), while the superficial velocity of the liquid 0.033-4.935 (m / s), the measurement data compared with the results of the calculation of predictions on homogeneous models and separate models get the conclusion that the gas superficial velocity and the liquid superficial velocity significantly influence the magnitude of the pressure gradient. The greater the superficial velocity of a gas or liquid, the greater the pressure gradient. The higher the JG value used will get an increase in the value of the pressure gradient and the higher the JL value used will also get an increase in the value of the pressure gradient. Therefore an assessment and investigation of the two-phase fluid and gas flow patterns with mini pipes are necessary to conduct. By testing the flow patterns and flow maps on a mini pipe, the aim is to obtain primary data from flow patterns and maps. The diameter of the test section is 1.6 (mm) in the form of a capillary glass pipe with horizontal position mixed between gas and liquid with dry air and water having a superficial gas velocity (JG) = 0.08-64.42 (m / s) and velocity superficial liquid (JL) = 0.02-3.09 (m / s). The results obtained from the study of flow patterns in the form of slugs, slugs annular, annular, wavy annular, churn and bubbly indicate these results are most similar to the map research conducted by Triplett et al.[11] Based on the description above, the discussion is centered on the vacuum fraction and flow pattern while the information about the pressure gradient in the capillary pipe with a viscosity variation is still lacking. This research is necessary to obtain information about the effect of superficial liquid and gas velocity and to obtain information about the effect of the viscosity of the water mixture -glycerin (40%, 50%, 60%, and 70%) to the pressure gradient in the horizontal position capillary tube with a slope of 45 °.

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

This research uses materials in the form of gas and liquid fluids. The liquid fluid uses distilled water and is mixed with glycerin with a percentage of 40%, 50%, 60%, and 70%. The gas fluid used is air with low humidity, which is obtained from the compressor. The equipment installation used in this study consisted of several main components: a water tank, a water pump, an air compressor, a pressure vessel, a mixer, a test section (a mini pipe with a diameter of 1.6mm, a length of 130mm), a connector and a separator. Supporting equipment in this study includes amplifier, computer, optical correction box, acquisition system, and video processing system. Measuring instruments used in this study include MPX, data acquisition, temperature indicator, pressure indicator, airflow meter, water flow meter. and thermocouple as shown in figure 1.

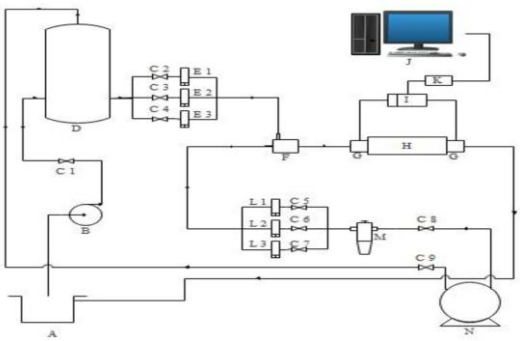


Figure 1. The Schematic of Equipment

H. Water Tank
I. Water Pump
J. Valve
K. Pressure Tank
L. Liquid Flowmeter
M. Mixer
N. Flange

H. Test Section
I. Pressure Transducer
J. Personal Computer
K. Data Acquisition
L. Air Flowmeter
M. Water trap

2.2. Calibration

Equipment that needs to be calibrated was a flow meter and MPX pressure sensor because the results will determine whether the measurement data is valid or not. In liquid flow meter calibration is done by using a liquid that is flowed within a period of 1 minute under conditions steady and fluid flowing according to JL governed by the flow meter. Then the liquid that comes out of the hose is inserted into the measuring cup to determine the volume or capacity of the liquid obtained for 1 minute. Meanwhile, the MPX pressure transducer was calibrated by connecting it to the water column manometer (vertical) with the water column height adjustment of 0 to 3 m under static conditions. The next step is to change the water column height settings on the manometer sequentially from the lowest to the highest level and take measurements with the MPX pressure transducer. The data obtained from the measurement of the manometer and pressure transducer are then made in a graph using Excel until finally a calibration graph is obtained as shown in figure 2.a - 2.b.

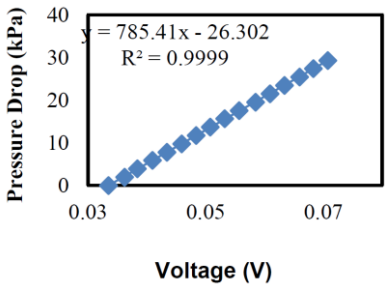


Figure 2.a. Calibration of MPX

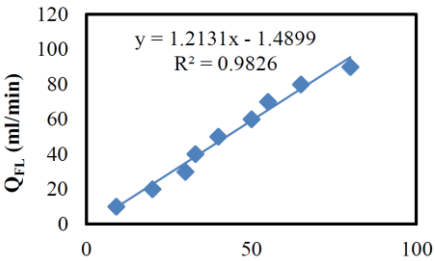


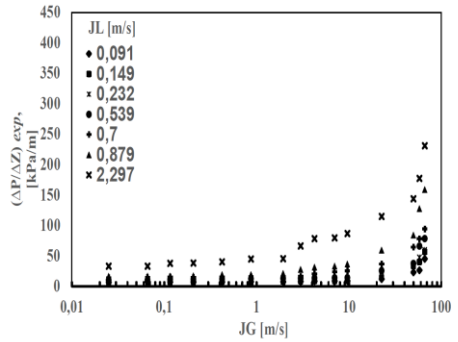
Figure 2.b. Calibration of Flowmeter (FL)

III. RESULTS AND DISCUSSION

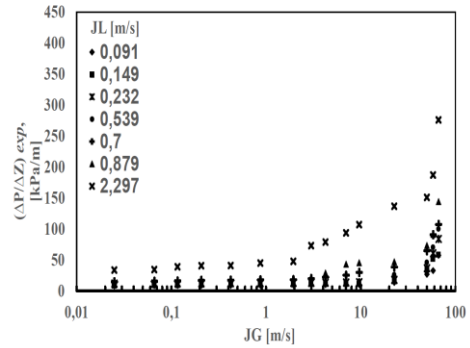
3.1 Pressure gradient

This pressure gradient study was carried out on a 1.6 mm mini pipe and was applied with a slope of 45 degrees with a mixture of glycerin and distilled water, each of which contained 40% (GL40), 50%(GL50), 60%(GL60), 70%)GL70) glycerin. The next step is to drain the fluid by regulating the superficial gas velocity (JG) and the superficial liquid velocity (JL) and on the gas and liquid flow meter. Recording the data was conducted by a computer that was already connected with acquisition data and pressure transducer with a sampling rate of 3000 data/minute.

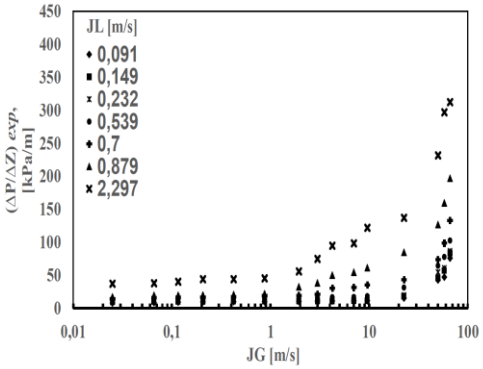
3.1.1. Effect of superficial velocity to the pressure gradient two-phase flow for GL 40, 50, 60 dan 70.



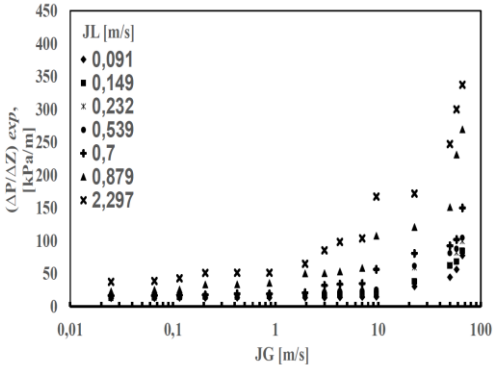
(a). Pressure gradient on GL40



(b) Pressure gradient on GL50

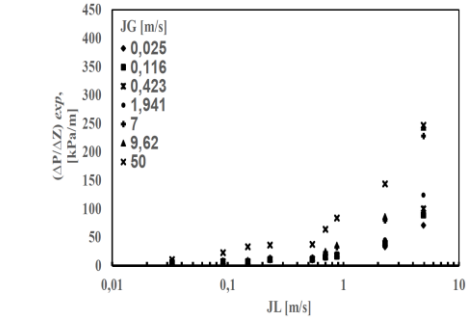


(c) Pressure gradient on GL60

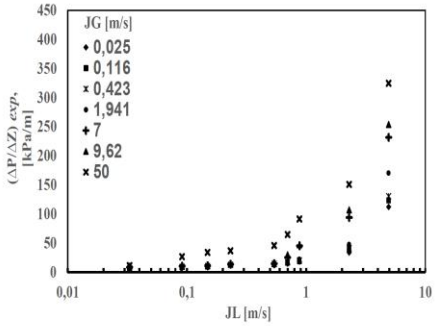


(d) Pressure gradient on GL70

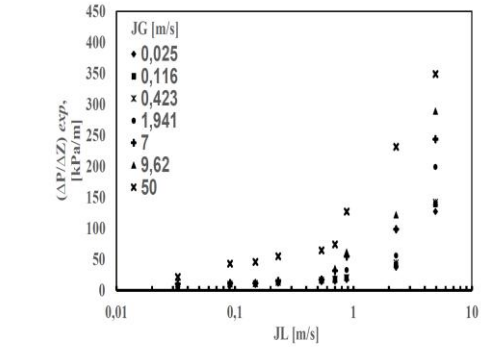
Figure 3. Effect JL [0,091; 0,149; 0,232; 0,539; 0,7; 0,879, dan 2,297 (m/s)] to the pressure gradient with vary of JG [0 - 66,3 (m/s)] for (a) GL40, (b) GL50, (c) GL60, (d) GL70



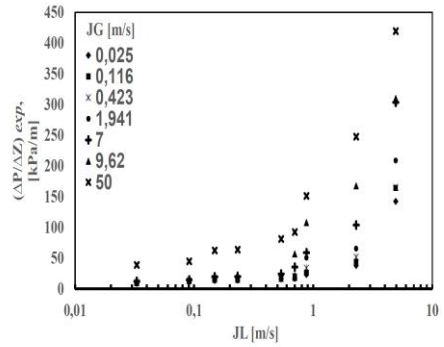
a) Pressure gradient on GL40



b) Pressure gradient on GL50



(c) Pressure gradient on GL60

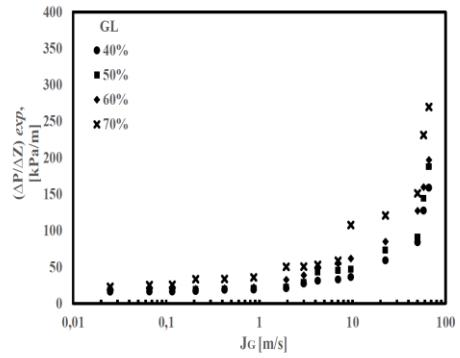


(d) Pressure gradient on GL70

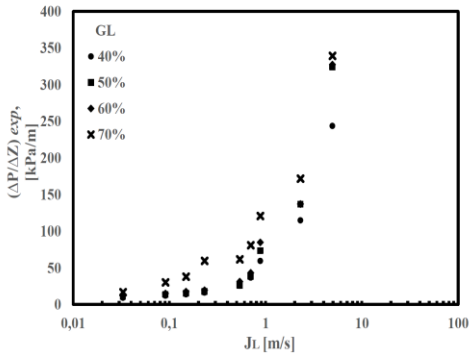
Figure 4. Effect JG [0,025; 0,116; 0,423; 1,941; 7; 9,62 dan 50 (m/s)] to the pressure gradient of JL [0,033 - 4,935 (m/s)] for (a) GL40, (b) GL50, (c) GL60, (d) GL70

The superficial velocity of liquid and gas to the pressure gradient with the variation of viscosity can be seen in figure 3.(a)-(d) and figure 4. (a)-(d). From this figure, it can be explained that increasing both liquid and gas superficial velocity increases the pressure gradient that occurs. This further justifies that the magnitude of the two-phase flow pressure gradient is linearly proportional to the magnitude of the fluid viscosity. In the previous experimental study, the pressure drop of the two-phase dry-plug flow in round mini-channels with their inner diameters ranging from 1.62 to 2.16 mm was studied. the result showed that in the dry-plug flow regime, the pressure drop measured became larger either by increasing the liquid superficial velocity[12].

3.1.2. Effect Viscosity to the pressure gradient



(a)



(b)

Figure 5. Effect fluid viscosity to the pressure gradient for (a) JL = 0,879 m/s and variation of JG for GL40-70, (b) JG = 22,6 m/s and Variation of for GL40-70.

Effect viscosity of the liquid to the pressure gradient with the superficial velocity of liquid and gas can be seen in figure 5. (a) and (b). From this figure, it can be explained that increasing liquid viscosity increases the pressure gradient that occurs. This further justifies that the magnitude of the two-phase flow pressure gradient is linearly proportional to the magnitude of the fluid viscosity. Meanwhile, the previous researchers [13] studied the effects of high fluid viscosity on the characteristics of flow. The experiments were performed on the flow using a test section of 26. mm ID and a 5.5. m long horizontal pipe with a range of liquid viscosity from 1000 cP to 7500 cP. The superficial oil and gas velocities vary from 0.06. m/s to 0.5. m/s and from 0.3. m/s to 12.0. m/s respectively. The result identified flow patterns

by Electrical Capacitance Tomography (ECT) and confirmed by videos recorded during the experiments. The pressure and liquid holdup data are obtained by using pressure transducers and the ECT system. The experimental results are compared with existing models and show significant discrepancies between low and high viscosity liquid and gas flows.

3.2.3 Time series of pressure gradient

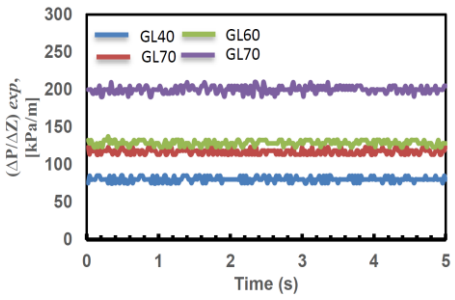


Figure 6. Comparison of pressure gradient on the variation of viscosity GL40-70

The pressure gradient on the time series on viscosities variation has shown in figure 6. Based on the figure, it can be explained that the higher viscosity so the higher the pressure gradient. This further strengthens the justification of the previous description in this paper and also justifies previous research[13]. On the other hand, the previous research that focus on the effect of viscosity of both phases on droplet size in the stable droplet generation regime was conducted. The result showed that at high viscosity ratio affected the droplet size. This was confirmed and elucidated through CFD simulations[14].

IV. CONCLUSION

The superficial gas (JG) value and the superficial liquid (JL) velocity greatly affect the pressure gradient velocity. The greater the value of JG and JL, the pressure gradient results show a significant change in value. The increase in pressure gradient in the tests that have been carried out from seven JL (0.091; 0.149; 0.232; 0.539; 0.7; 0.879 and 2.279 [m / s]) with a variation of JG (0 to 66.3 [m / s]) has increased. Likewise, the same case was happen for the influence of JG with a range (0.025; 0.116; 0.423; 1.941; 7; 9.62 and 50 [m / s]) with variations in JL (0.033 to 4.935 [m / s]). Pressure gradients at JG = 0.066 (m / s) and JL =4.935 (m / s) with a viscosity of GL40 produce an average pressure gradient of 80,366 (kPa / m), GL50 produces an average pressure gradient of 117,202 (kPa / m), GL60 produces an average pressure gradient of 128.708 (kPa / m), and GL70 produces an average pressure gradient of 200,086 (kPa / m). Thus the tests carried out showed, the greater the fluid viscosity, the greater the resulting pressure gradient. In accordance with the results of research conducted with increased variations in the viscosity of the liquid causes the liquid will be more restrained or blocked to move, so the results show the pressure gradient value also increases.

ACKNOWLEDGMENT

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★★★

EXPLORING JOB HOPPING BEHAVIOR AMONG MANAGERS OF CASUAL DINING RESTAURANTS IN KLANG VALLEY AREA, MALAYSIA

[1]HAZRINA GHAZALI, [2]KHAIRUNNISA MOKTHAR

[1,2]Department of Foodservice and Management, Faculty of Food Science and Management, University Putra Malaysia
E-mail: [1]hazrina@upm.edu.my, [2]khairunnisa@gmail.com

Abstract - The job hopping phenomenon has become problems to many organizations because employee job hop for various reasons. A large degree of employees' job hopping may be detrimental to both the organization as well as the employees. Therefore management plays a significant role as organizations' success is dependent on management's ability to retain valuable and talented employees. Employees tend to leave an organization that cannot match with their expectations and move to another organization through the availability of many options of the job vacancy. This crisis continues to represent one of the most significant challenges faced by the restaurant industry. The purpose of this study is to explore empirically managers' views on factors that may lead to job-hopping behaviour in the casual dining restaurant. This qualitative study collected data from 10 managers of casual dining restaurant by using the semi-structured interview. Findings revealed three main reasons associated with job hopping behaviour that are career growth, financial and benefits and customers complaints. These findings provide a better understanding for restaurant operation and human resource management to view employees' job hopping scenario and how the organization can control this job-hopping behaviour decision from occur. Previous research on job hopping mainly focuses on non-managerial employees' perspective and this study is believed to be the first empirical research in Malaysia restaurant industry particularly in the casual dining typed of restaurant. Hopefully, this study will help the restaurant owners or operators to formulate effective strategies to retain employees from leaving the industry.

Keywords - Job Hopping Behavior, Career Growth, Financial And Benefits, Customers Complaints, Managers, Casual Dining Restaurant, Malaysia

I. INTRODUCTION

A person changing jobs frequently is termed as a job hopper. An employee who left an organization that did not fulfill his expectations when an alternative position was deemed normal in another organization. Job hopping phenomenon was discussed by different researchers in their studies. Some researchers examined the job hopping behavior in specific industries (e.g., Khatri et al., 2001) while some investigated the generational differences in job hopping resulted from different work attitudes (Ahmed et al., 2014). There are different reasons for employees' job hopping. For instance, they would try to find the jobs that fit their preferences such as having high level of freedom in jobs and tend to quit jobs when they find that the jobs do not meet their expectations (Cennamo& Gardner, 2008), when they are not satisfied with the work environment or do not like the job they are currently in (Walker &Sorce, 2009). Lavoie-Tremblay et al. (2010) believed that staff who job hop with their business have a low level of allegiance and recognize the use of job hopping as a career advancement instrument. In other research has stated that job hopping behavior is an individual strategy to achieve his/her vision of life.

A job hopper has his own reasons and objective to be achieved for job-hopping. By having previous knowledge in previous work, it make job-hopper can be easily accepted in a variety of organizations and new employer to see his/her wide marketability. Besides including the reasons for job hopping in the definition, some previous authors (Settersten& Ray, 2010) even renamed job hopping as a work shopping. They considered that it is not necessarily due to restlessness or fickleness that individuals who change employment often. When individuals change employment with a clear objective or accomplishment, working in distinct businesses is an intelligent approach for them to comprehend distinct cultures of the office, boost wages and boost their duties with each shift. People who change employment are called work shopping with clear reasons. On the contrary, frequently switching employment without credentials is considered a hopping job. Their movements are not due to their desire to change, but to their absence of negotiating stance or abilities or qualifications. They are attempting to discover their foundations. Whether job hopping is simply described as frequently altering employment, switching employments for distinct purposes, or even renamed as work shopping, it is evident that changing jobs is the key component when defining job hopping commonly or within a brief span of time. There had been plenty of studies conducted by past researchers in the context of managing employees but very little information is available on job-hopping behavior. Most of the studies were on burnout, job stress, job characteristics, and retention and turnover intention. It is common that in food and beverage industry, the occurrence of turnover cases is very high and costly. Therefore, this research aims to explore reasons of job hopping behavior in the casual dining restaurant.

II. METHODOLOGY

2.1. Materials and Procedures

This study is aimed to explore job hopping behavior among managers in casual dining restaurant in Klang Valley area, Malaysia. This research employed qualitative method with semi-structured interview. Semi-structured interview has been chosen for this research as it has the flexibility to change the order of questions to ask based on the direction of the interview. Additional questions can be asked to lead respondents to elaborate more on their response. The questions were shown to the respondents and describe on what to be discussed in the interview session before the actual interview session is conducted to reduce the misinterpretation and the increase in the validity of the results. Along the interview session, the respondents were guided to provide more information by elaborating their answers. Interview session took approximately 30 to 45 minutes.

III. RESULTS AND DISCUSSION

3.1. Demographic Profile of Informants

There were a total of ten informants who had shared their thoughts regarding job hopping behavior. Among the informants, four of them were males and six were females. In term of job position, four were restaurant managers, four were supervisors and the other two of them were assistant manager. There were eight Malays, one Indians and one Phillipines participated in this research. All of the informants who participated in this study have experienced of job hopping from a minimum of two times switching to a maximum of six times throughout their career life. This study discovered three main reasons of job hopping among the managers of casual dining restaurant. Career growth, financial benefits and customers' complaint were proved as reasons of job hopping behavior. The following excerpts are the feedbacks from managers on career growth dimension.

'The other reason why I job hop was because I wanted to find new experience'- (Mr. T, Restaurant R)

'I just want to try another experience. That's it' – (Mr. P, Restaurant E)

'Because I wanted to move to another country and also I wanted to gain new experience.' (Ms. P, Restaurant H)

'The other reason I job hop was also because I wanted to be promoted at another place'- (Ms. D, Restaurant B)

'Yes, rather than I have mentioned, I also wanted to gain new experience for job hopping'. (Ms. N, Restaurant D)

'I job hop because I wanted to try new experience'- (Mr. R, Restaurant G)

Findings from this study similar found in previous research which indicated that staff who would like to be promoted or upgraded to the title would prefer job hopping because those factors were powerful enough for them to move their present job to another one (Prayana, 2014).This study also discovered financial benefits as the reason why job hopping occurred. Generally, job hopping behavior is always related to monetary and benefits. They were looking for an organization that could pay them better and provide attractive benefits. Based on quotation from the informants, it is clearly highlighted the importance of good salary offered. They accepted other offer from other organizations as long as it is more than current amount of salary they earned. It is agreeable that increase of living cost especially in the urban area such as Klang Valley has influenced the managers' decision to job hop in relation to their socio-economic status enhancement. These informants in the interviews had commented and explained their reason of why they job-hop to another places. The following excerpts are the feedbacks from managers.

'There is once I job hop because the company did not pay me enough and it was not worth what I have contributed, so I decided to find new job that pay me better salary.'- (Mr. T, Restaurant R)

'I job hopped because at that time sales was not good and it was hard for employees to do over time. Even though I was full timer but they only paid me for basic salary'- (Ms. N, Restaurant D)

'The other reason why I am going to find the job is because salary here is one of the lowest salary in restaurant in this mall.'- (Mr. R, Restaurant G)

'The second reason why I job hop was because the salary was paid late. Moreover, the salary is not much rather than here.'- (Mr. K, Restaurant F)

Compensation power along with benefits cannot be overlooked as most studies have shown that the adverse effects of compensation can lead to important worker discontent and difficulty in retention of staff. Osibanjo et al. (2014) revealed that retention of employees is linked to compensation positively and substantially. The last findings from this study were somehow interesting and surprising. Findings discovered that customers' complaints were also the reason of job hopping among managers of casual dining restaurant. Kim (2007) stated that in the hospitality industry, where the worker often meets challenging and hard clients, such situations are not unusual and need to treat clients quickly in order to obtain more competitive advantage. The worker has to deliver quick, effective and professional service to clients in the restaurant sector. Therefore, it is no wonder that the managing difficult customers which can be considered as stress at work can result from the conduct of job hopping.

'I have so many experiences in receiving customer complaint. It was really saddened me till I feel like I want to change my job'- (Mr. T, Restaurant R)

'I have been scold for so many times, and it was one of the reason why I wanted to find a new job'- (Ms. S, Restaurant K)
'My greatest disappointment was received customer complaint. It really makes me sad even if I only think about it'- (Mr. P, Restaurant E)
'I have ever received a complaint from customer that involved Head Quarters employees. From that I have been scold even when it was not my fault. For that reason, I even felt wanted to quit the job'- (Ms. N, Restaurant D)
'Have received customer complaint and it was normal for us and that was all that makes me consider to leave the job'- (Ms. A, Restaurant M)

IV. CONCLUSION

In conclusion, this research has fulfilled the objective of study on exploring reasons on job hopping behavior among managers of casual dining restaurant in Klang Valley area, Malaysia. This paper disclosed three reasons associated with job hopping behavior. Based on interview results, career growth, salary and customers complaints were associated with job hopping behavior. Findings from this study were interesting and somehow surprising. Higher wages are often quoted as the primary reason that individuals commonly change employment. However, customers' complaint reasons associated with job hopping somehow surprising and need to explore more in details for future research. This research is helpful as it plays the roles as a reference for the restaurant operator in order to provide better compensation package, good career advancement path and training on managing consumers.As an employee is an asset of the organization, formulation on effective strategies on minimizing employees' intention to job hop very important in order to produce productive and committed employees and ultimately increase sales of the restaurant.

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THE STRATEGIC MANAGEMENT PROCESS IN IMPROVING OF INDONESIAN DEFENSE INDUSTRIES

[1]NOVKY ASMORO, [2]KHAERUDIN, [3]MARSONO, [4]SUPANDI

[1,2,3,4]Indonesia Defense University, Indonesia Defense University Indonesia Defense University, Indonesia Defense University
E-mail: [1]novkyas@gmail.com, [2]khaerudinsyahid@yahoo.co.id, [3]marsonopsk@yahoo.co.id, [4]pendi.supandi@yahoo.co.id

Abstract - Industrialization process through increasing the production capacity of the national defense industry are part of the natural process that will be experienced by a nation including Indonesia as part of developing countries that shift from modern industrial country with a constructive to competitive industrial system. Based on qualitative analysis on the Porter 's Diamond model as a tool to design a concept of increasing the competitive power of the defense industry Human Resources (HR) in Indonesia, it will be known how the opportunities for profitable companies consistently. Some of the things that can be attempted to achieve these conditions include planting commitment as an industrial defense base whose main goal is the development of the strength of the national defense system with the dual use concept, reconstructing harmonious relations with the Indonesian Armed Forces (TNI), the availability of local supporting industries and more progressive research & development programs to achieve production levels and efficient financing.

Keywords - Defense Industry, Competitive Power of HR, Dual Use, Profitable, Research & Development

I. INTRODUCTION

National defense industries must be organized comprehensively in strategic management, in order to achieve competitive advantage. It is necessary to determine the strategy formulation based on analysis of internal and external environmental conditions so that the blue print formulation of the company will be more reliable. In order to apply the formulation to be acceptable, it is necessary to do a stage of analysis of projections of the company's performance conditions in the future by determining the most realistic strategy implementation. The entire stages need certain approaching and designing as the concept of strategy evaluation for assessing performance and company competitive advantage

II. COMPETITIVE INDUSTRY OF DEFENSE IN SOME THEORY REVIEWS

NO	Economic Logics	Current Condition	Remarks
1	Arenas	Product : Naval & Merchant Shipping Market Segment : MoD, Limited Export Geographic Areas : Ina & East Timor Value Creation Stages : JoP & ToT	Producing with sophisticated tech for spreading the product, market segment, Geographic ares and VC stages
2	Staging	Speed of Exp : Slow Seq of Iniciatives : Slow (SOE's) Scale Adv : Slow Scope & Replication Adv : None Unmatchable sevice : After sales service Prop. Prod. Services : After sales service	Transforming to private business for developing staging of management business.
3	Differentiators	Image : By order Customization : By order Price : More competitive Styling : By order Product Reliability : Standardization	Differentiations with SBU for developing the products (non-shippng) and maintenance services
4	Vehicles	Int Development : Workers rationalization Joint Venture : No Licensing : No Acquisitions : ToT with DSEM Korea	Developing competitiveness firm with "Offset" trade scheme

Table (a) Strategy Mapping of Defense Industry Elements

To do analysis on the competitive value of the defense industry then it needs some basis of theory especially in the devotion of defense economic science perspectives such as:

1) The Theory of Elements of Strategy. As with other industries, the existence of the defense industry remains based on certain strategies to create competitive advantage in addition to sustainable profit growth. As a business activity, the strategy concept is based on the question where business activities take place (Arenas), how to manage the business (Vehicles), how to achieve excellence in market competition (Win), how the stages and processes work (Sequences) and how to achieve a return (Economic Logic) [1]. These elements are closely related to the concepts developed for the defense industry to achieve competitive advantage which of course needs to be refined in a more specific systematics strategy.

2) Porter's Diamond Model. Porter's Diamond Model if assumed as dependent variables of company competitive advantage (CoF), the principle classifies four main factors as independent variables that support a company's competitiveness namely Condition Factor (CF), Demand Condition (DC), Related & Supporting Industry (RSI)) and Firm Strategy & Structure Rivalry.

$$CoF = \{ f (CF, DC, RSI, FR, G, O)\} \quad (1)$$

The four main factors will be more effective when driven by two other factors, namely government (G) and opportunity (O) and all of them support each other [2].In general, to have high competitiveness, the perspective of specification of these factors can be categorized on aspects of skilled labor, culture, government support and the strength of technological improvisation (advanced technology).

3) Level of Strategy Theory. In principle, there are 3 levels of strategy known in a company. The first level is Corporate Level Strategy where this level of strategy is emphasized on defining the company's business so that it can form a corporate format as a whole by bringing together all the business lines that are owned in achieving competitiveness. The second level is the Business Level Strategy, at this level explained the form or pattern of industrial strategy adjusting shots of certain market segments to improve the competitiveness of companies. The third level is Functional Level Strategy, at this level a strategy is set at a more technical level by empowering several management functions in the company, such as marketing, funding and operational strategies [3]. If this theory is applied to the defense industry, then what needs to be considered is how to map the strategic review in this case the company benchmarking, conduct internal and external analysis based on the tools used and the determination of the company's vision and mission.

III. ANALYSIS OF THE STRATEGY CONCEPT OF INDONESIAN DEFENSE INDUSTRY IN THE STRATEGY FORMULATION AND DEFENSE ECONOMIC PERSPECTIVE

A. Porter's Diamond Model in the External Analysis Framework. To carry out Porter's Diamond Model analysis, the approach used is to measure several parameters on specific factors at Indonesian Defense Industry as an industry included in the Defense Industrial Base category. In the perspective of economic defense the above perspective is expected to be able to support the national defense system by having a function in the concept of dual use [4].

(1) Condition Factor. Analysis of the porter's diamond model on condition factors is very relevant to the state power conditions, namely economy (E), military (M), critical mass (Cm), strategy (S) and political will of the government (W). However, the condition of state power is actually inversely proportional to its external conditions such as territory and population as well as natural resources called External Super Power [5].

$$P = ((E + M + Cm) \times (S + W)) / ESP \quad (2)$$

For Indonesian Defense Industry including Human Resources and Research & Development (R & D) issues will not be overcame if there is no commitment by the government to gradually drive the defense industry to become more independent with increasingly professionalism of human resources and R &D activities.

(2) Demand Condition. The customer needs factor is based on the demands of consumers' needs for sophisticated warships in terms of electronic equipment, navigation, weapons control, and anti-mine systems that significantly encourage the production capacity of Indonesian Defense Industry to improve its competitive advantage. To explain clearly regarding the relation of defense acquisitions among its variable, it could be defined by

Defense Acquisition = Government (Ministry of Defense) + Industry (Supplier) (3)

From the model of the defense acquisition equation as above, it can be seen that the process is highly dependent on the existence of government variables through the Ministry of Defense and the defense industry as suppliers [6].

(3) Related and Supporting Industries. If viewed from correlating industries aspects, the actual existence of Indonesian defense industry as put the dual use concept. For illustration, PT PAL Indonesia as the State Owner Enterprise (SOE) in Indonesian Shipping Industry runs its business in structure of naval 20shipbuilding and merchant shipbuilding. The implementation carried out by Indonesian defense industries in utilizing domestic supporting industries

have been conducted by PT. Krakatau Steel and PT. Barata Indonesia to supply steel needs and several components or raw materials of ships. Those SOE's collaborate in financing with the Indonesian Import Export Financing Institution (LPEI) and any Banks such as Bank Mandiri, BRI and BNI [7]. To utilizing relations between local industries, PT. PAL Indonesia has designed a centralized company such as General Engineering and Repair &Maintenance in an industrial area to get efficiency of transportation cost.

Figure Layout of Facilities and Supporting Industries of Defense Industry (PT. PAL Indonesia)

(4) Firm Strategy, Structure and Rivalry. The condition of the structure of state-owned enterprises is quite fluctuating followed by receipt of the value of profit and loss which tends to be stagnant time to time. To illustrate the production of Indonesian Defense Industry in the form of commercial ships and warships is actually very elastic on the supply and demand side.

$$Ed = \frac{P1 + P2}{Q1 + Q2} \mathrm{X} \frac{\Delta Q}{\Delta P} \quad (4)$$

The elasticity coefficient of a product (Ed) is a bargaining position in the market that depends on changes in the price of demand (P), the number of requests (Q) and the Holding cost rate per unit (H) that occurs [8]. With the structure of the SOE's company whose existence without competitors. Those industries run a firm strategy with a joint of production and transfer of technology (ToT) schemes. Through this policy, PT. PAL Indonesia as Indonesian Shipping Industry obtained the ToT from South Korea's Daewoo Shipbuilding & Marine Engineering Co., Ltd. to manufacture submarines for the Indonesian Navy. Under the Defense Industry Law No. 16 of 2012, this "intervention" is able to shift monopsony power from elastic to inelastic for national defense industry products to be more competitive and to achieve the expected national capacity building. As an implementation of Porter's Diamond Models, in addition to the four diamond factors, there are two external factors that influence the success of the model, namely the role of "Government and "Chance". The role of the government through the defense industry law is certainly expected to be able to encourage independence and create competitiveness for defense industries are also able to stimulate the country's economic growth (GDP). Based on the expenditure approach, in the economic growth equation (Y) as the dependent variable, government spending (G) is one of the independent variables that affects it besides consumption (C), Investment (I) and Export Import (X-M) [9].

Y = C + I + G + (X-M) (5)

In relation to the chance factor, of course we do not want things to be contradictory regarding the government's policy. Some unpredictable events such as the economic crisis, natural disasters and so on are not expected to make certain defense industry

collapsed because it was too dependent on any government policies.

NO	Parameters	Capabilities	Acquisition Planning Concepts
1	Factor Conditions	Good Nat. Economic Growth Good Strategic Concepts Good Infrastructure	Rising Qty of R & D Rising Qty of HRD
2	Demand Conditions	Hi-tech Shipping Production	Rising the Limited Production for offering consumer needs More focus for any sophisticated tech (electronic & navigation equipment, weapons system)
3	Related & Supporting Industries	Good Industry Layout Good Relationship with Finance Corporate & Raw Materials Industry	More innovative for the input production Rising the effectiveness between sub unit into Layout Design Rising the relationship with main component and sub parts industry
4	Firm Strategy, Structure and Rivalry	Good Scheme Trade (ToT & JoP)	Rising Scheme Trade exp. ToT & JoP With Others Firms Moving to New Paradigm Structure "Base on Investment"
5	Chance	Good politics, economic & security national condition	Anticipating global crisis with having a good finance fundamental
6	Government	Strong Position with UU No. 16 th 2012	Not really dependently with Government Regulation for guarantee the Stability of Firms Moving to be more commercial Firm

Table (b) Capability Mapping and Planned Acquisition of PT PAL Indonesia in the Porter's Diamond Model Concept

B. The concept of Blue Print Formulation in the Level of Strategy Level. Indonesian Defense Industry as one of State Owned Enterprises obtain the strategy implementation phase through conducting particular studies that related to the blue print formulation of the company by fulfilling a number of rules from the level of strategy.

(1) Corporate Level Strategy. At this level, Indonesian Defense Industry needs to define the format as a defense company by integrating its entire division into several profit-oriented activities. Those steps are called diversification of products or services where maintenance and repair services are currently able to drive company profits other than product sales. In addition to minimizing total annual costs of a product that has a specificity on the maintenance cost, based on the economic order quantity perspective the strategy is carried out by making efficient costs incurred as a result of ordering and maintaining existing product inventories [10]. Strategic efforts for alliances need to be improved by a joint of production scheme or transfer of technology which has now been carried by the DSME submarine company from South Korea and PT. PAL Indonesia.

(2) Business Level Strategy. To achieve some targets which would be more appropriate market segment, if Indonesian Defense Industry began to have the concept of establishing a Strategic Business Unit (SBU) that develops capabilities or specific products. Reference to PT. PAL, it has some SBU's such as Docking Service, products of Missile Fast Ship and Fast Patrol Boat. The independence of the SBU is expected to be able to encourage the company's competitive advantage in addition to efforts to improve internal management of the divisions within the previously formed organizational structure.

(3) Functional Level Strategy. The level of strategy at a more technical level is to empower several internal functions of the company such as rationalizing

employees in terms of HR management, B to B policy for marketing strategies and collateral loan steps to funding related banks.

IV. CONCEPT OF EXECUTION STRATEGY AND STRATEGY EVALUATION

A. Strategy Execution in an Effort to Achieve the Best Performance. If the strategy formulation has been determined by considering several internal-external analyzes and the blue print has been determined, the execution of the strategy implementation will most determine the performance of the company. For Indonesian Defense Industry related to the execution of strategies that are considered appropriate include:

(1) Benchmarking Strategy. The opportunity to implement this strategy is basically very open with the partnership that has been undertaken by Indonesian Defense Industry with several Strategic Business Units from foreign defense industries. The benchmarking process in addition to issues related to production strategies, Indonesian defense industry also needs to adopt the financing system pattern, research and development policy, marketing strategy to the corporate culture that is considered positive for increasing the competitiveness of the company.

(2) Corporate Governance. Particular strategies need to be executed by Indonesian Defense Industry in order to improve its performance by implementing the principles of corporate governance. Based on the major principles of corporate governance, those principles need to be focused is an effective and efficient organizational structure, independence in each function of the company's parts and a systematic pattern of operations [11].

(3) Work and Alignment Team. To achieve team collaboration and alignment processes in supporting the achievement of sustainable competitive advantages, it is necessary to consider two basic elements of strategy execution namely resources and capabilities [12]. For this reason, Indonesian Defense Industry in conditions that have not been maximized profit should need to pay attention to the two things, namely the competence of experts and specialists must be distributed proportionally. This includes through job rotation, job enlargement and job enrichment so that company efficiency is achieved [13].

(4) Excellent Acquisition Service. In a defense acquisition perspective this holds a central position where the government as a single consumer must have a good relationship with the industry. The new paradigm of partnership is based on the value, partnership and win-win solution is the best pattern for the government and defense industry. With such a relationship, Indonesian Defense Industry as a supplier will get feedback and complaints after sales from users that are useful for increasing their competitiveness to be more competitive in the future.

B. Draft Strategy Evaluation Concept. As the last thing in the management process, the evaluation phase is still very weak in implementation. For Indonesian Defense Industry and other SOEs, the evaluation system is generally carried out as a follow-up of the performance and financial auditing process by both the internal auditor and the external auditor.

NO	Parameters	Description	Actual Situation
1	Strategic Views	Competitive Dynamics	Monopsonic Market Elasticity Product
2	External Analysis	Porter's Diamond Model	Condition Factor (State power), Demand condition (rising customer needs but limited sophisticated tech)
3	Strategic Intens (Vision and Mission)	World Class Shipping Industry National Defense, Customer Preference & Prosperity	Good for guiding the direction of firm planning
4	Blue Print Formation	Corporate Level Strategy Business Level Strategy Function Level Strategy	Diversification service for ship repairing and SA (ToT with DSME) "None" for SBU HR Rationalization and B to B policy
5	Strategy Implementation	Strategic Execution	Benchmarking strategy, corporate governance, Team work & alignment and service excellent acquisition
6	Strategy Evaluation	Strategy Evaluation	Internal Auditor Definied strategy outcomes : measuring variable, point of review & corrective actions

Table (c) Overall Strategic Management Concept Design of Indonesian Defense Industries

As a defense industry with a world class vision, it is necessary that Indonesian Defense Industry designed a more standard and accountable concept of evaluation strategy. This can be done as strategy outcomes with parameters, namely company performance variables that are more measurable, validity of points of reviews and corrective actions for improving performance and competitiveness of the company to be better. To describe the overall Draft of Management Strategy Concept based on Porter Diamond Model in developing the capabilities of Indonesian defense industries might be checked at table on below

V. CONCLUSION

Strategy of Indonesian Defense Industry to achieve competitive advantage based on strategic management systematics in a defense economic perspective must raise three important action programs such as the planting of commitments as an industrial defense base whose main aim is the development of the strength of the national defense system with dual use and reconstructing harmonious relations with the TNI as well as the availability of supporting industries local and more progressive research & development programs to achieve production levels and efficient financing. In principle, those are alternative input for strengthening the national defense system. Those strategies need to be formulated or implemented by the ranks of the Ministry of Defense, the Ministry of Industry and the Ministry of Research & Technology and several other relevant stakeholders.

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DETERMINATION OF TRAFFIC SAFETY WITH METHODS ALTERNATIVE TO TRADITIONAL METHODS

[1]CORUHEMINE, [2]TORTUM AHMET

[1]Department of Civil Engineering College of Engineering and Natural Sciences Gumushane University, Gumushane, 29100, Turkey
[2]Department of Civil Engineering College of Engineering Ataturk University, Erzurum, 25240, Turkey
E-mail: [1]eminecoruh@gmail.com, [2]atortum@atauni.edu.tr

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 thousand people 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.

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

[1]YU-PIN LIAO, [2]SHIN-KUAN CHIU

[1]Chairman's Office, Winstar Display Corp., Taichung, Taiwan
[2]Ph.D. Program of Business, Feng Chia University, Taichung, Taiwan
[3]Department of International Trade, Feng Chia University, Taichung, Taiwan
E-mail: [1]panjc@winstar.com.tw, [2]skchiu@fcu.edu.tw

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.

Keywords - 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

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	△	○	○

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

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:

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

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

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

where $\mathbf{V}_1,...,\mathbf{V}_M$ are functions of $\boldsymbol{\theta}$. Typically, $l_{\beta=\hat{\beta}}(\boldsymbol{\beta},\boldsymbol{\theta})$ 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.

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

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:

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

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.

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

Table 2. NUMBER OF ORDERS AND PRODUCT DEMAND

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

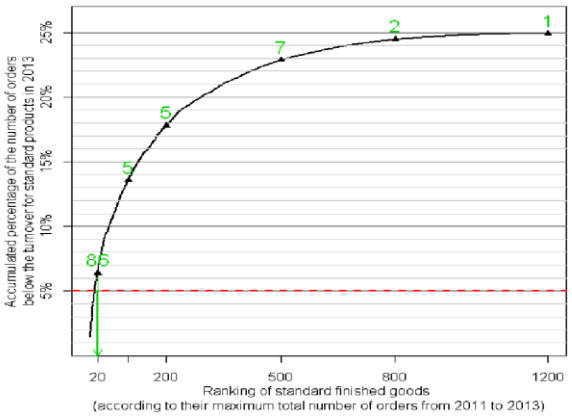

Figure 1. Maximum total number of orders (2011–2013).

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:

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

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

Table 3. Linear Mixed-Effect Model Versus the Linear Model. " - ": 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 ($N \leq 6$).

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.

	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

Table 4. Error Indicators for the Four Forecasting Methods.

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:

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

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

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

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 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.

	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	○	○	※1
Linear model	1	1,295		○	
ARIMA(2,2)	20	≤ 72	○	○	○
Exponential smoothing method	240	≤ 6	○	○	○

Table 5. Comparison of the Four Models.
※1 This effect is nonsignificant

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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FACULTY RESEARCHERS AND NON-RESEARCHERS IN THE CONTEXT OF TEACHING PERFORMANCE AND PERSONAL PROFILE

[1]JAKE M. LAGUADOR, [2]JOSEPH CEZAR L. DELIGERO, [3]CECILIA C. PRING

[1,2,3]Lyceum of the Philippines University, Batangas City, Philippines
E-mail: [1]jakelaguador@gmail.com

Abstract— Every Higher Education Institution needs to develop faculty researchers from its faculty line up who can share their time and expertise to produce research outputs while performing their responsibilities as classroom teachers and sometimes as school managers. This study aims to compare the result of faculty performance evaluation from students and the faculty profile when they are categorized based on their research involvement. Descriptive type of research method with inferential statistics using Chi-square test and Guttman's Coefficient of predictability as statistical tools was utilized to describe the result of the study. Results showed that there are more female master's degree holders with hourly rate from Php 251 to 350 who have active research involvement than males and bachelor's degree and doctorate degree holders. Faculty researchers have significantly higher performance evaluation rating from the students compared to non-researchers. Those with higher Instructional and Diagnostic expertise among faculty members showed higher possibility of becoming faculty researcher. Faculty members may also be required to write books or instructional manuals as a form of research output. If they will be written their own material to be utilized in their own respective classes, mastery or the subject expertise may be fully achieved. They were encouraged to conduct more funded researches from the government and private agencies during the transition period of the Philippine Education in the K-12 implementation.

Keywords - Faculty Member, Researcher, Non-Researcher, Teaching Performance.

I. INTRODUCTION

Research cannot be taken away from the important functions of teachers especially in higher education institutions. Being the facilitators of learning process, they are equipped with various teaching strategies and research skills on how to address educational problems and issues of the academic community. Elton [1] emphasized that it has become increasingly clear over the past decade that the question of a positive link between research and teaching has no simple or general answer. At the same time, there may well be a positive link under particular conditions. Borg and Liu's [2] study problematizes the notion of teacher as researcher by highlighting many interactive personal, interpersonal, and institutional factors which shape the extent to which teachers can be research-engaged.

Teaching effectiveness and research productivity are complementary. Much of the rationale for the existence of research universities is that these two activities are so mutually reinforcing that they must co-exist in the same institutions [3]. Studies have assumed the nature of this relation and characterized it as one that exists between externally defined indicators such as teaching effectiveness and research productivity [4].

Aside from delivering instruction, teachers are also responsible in conducting research for personal and professional growth as well as part of the continuous improvement of the university where they belong. This is also an important part of the faculty performance evaluation aside from teaching performance. Teaching performance could not only be measured through classroom instruction. In fact, Lyceum of the Philippines University – Batangas (LPU-B) has continually enhancing its faculty evaluation instrument through the initiative of Human Resource Management and Development Office and Research and Statistics Center wherein research involvement is part of the consideration in assessing the performance of faculty members. Candidates who may be effective classroom teachers may not be as skilled in writing about their instructional practice [5]. Teachers' engagement in doing research is less frequent, with three main reasons given: lack of time, interest and motivation. The motivations for doing research, however, tend to be more extrinsic than intrinsic; the majority reported doing research for promotion or graduation, while few do it to improve teaching or out of personal interest [6].

Determining if the majority of researchers are dominated by young ones or old ones, single or married, with doctorate, master's or just bachelor's degree holders. Sometimes, age doesn't matter in conducting research, but others might believe that the older teachers with higher educational attainment and experience in teaching and research could contribute and conduct better research outputs than young ones. According Reid et al.[7] that large numbers of teacher education research academics nearing retirement; a diminishing capacity among faculties to recruit young academics in the discipline who are both 'research ready' and 'teaching ready'.

Viewing the image of research benefits not as a whole but through its part specifically during its production process where great learning occurs and transpires to the team members of the organization would create clear reflections on how to become critical thinkers as

well as systematic, organize, innovative, creative, dynamic and proactive professionals.

Favilla and Bloch [8] found out that researchers were more likely to have received research training than non-researchers, spent more hours a week on research at the time of the survey and during the previous 5 years. Researchers devoted more time to academic teaching and acquisition of higher degrees. Twice as many researchers as non-researchers had published peer-reviewed articles; the average number was substantially greater. The researchers had obtained funding for their studies far more often than their non-researching counterparts; the average amount was 100 times greater.

Sharing what they have learned through conducting researches to the students and to the academic community would make them better learners, effective teachers and nation builders while reaching the borders of competitive world.

This study is intended to determine the significant relationship and differences of faculty researchers and non-researchers. On this context, it is delimited to the concept that faculty researchers are those faculty members who fervently conducting institutional research studies for their respective departments with at least one completed research either institutional or college for the last three years while the result of students' evaluation on teaching performance will be taken for the last three years. Non-researchers are faculty members without completed institutional research and they will be drawn randomly from the roster of faculty members of different colleges to compare their faculty performance evaluation results against the performance of considered active researchers.

There is also consideration in civil status and gender issues between single and married faculty members. Singles have fewer responsibilities against mothers with more obligations and tasks to attend to at home than fathers with also lots of responsibilities but more on related to their job which is also in teaching profession. These could somehow be their reasons for engaging or rejecting research undertakings of the university.

Furthermore, educational attainment has something to contribute to the amount of hourly rate. Could it be true that faculty members with higher hourly rate have more number of completed institutional researches than with lower salaries or maybe the full-time teachers specifically the plain teachers have more time to conduct researches than those part-timers?

There are few studies differentiated the teaching performance and profile between faculty researchers and non-researchers, thus this study was pursued. The findings of the study would serve as a reference for the faculty members to enhance or improve their teaching strategies through conducting either action or institutional research. Since it is not only the responsibility of the Faculty members to focus on instruction but also to engage their quality time in providing substantial research outputs to be utilized by the students, the organization and the community at large.

II. OBJECTIVES OF THE STUDY

The study aimed to determine the preliminary identity sketch of the faculty researchers and non-researchers in terms of age, gender, civil status, employment status, educational attainment and hourly rate; and students' evaluation of teaching performance result from 2010 – 2013; to compare the result of the teaching performance and test the differences between researchers and non-researchers; to test the difference in the profile variable between two the groups; to determine the differences between faculty researchers and non-researchers when they were grouped according to profile variables; and to determine which profile variable included in the study and which teaching performance criteria best predicts the possibility of becoming a faculty researcher.

Ho: There is no significant difference between faculty researchers and non-researchers when they were grouped according to profile variables.

III. METHODS

A. Research Design

The study will use a descriptive type of research method using documentary analysis in data gathering wherein the names of the faculty members with completed and on-going Institutional researches were obtained from the Research and Statistics Center of the University while the results of faculty performance evaluation result were obtained from the Human Resource Management and Development Office through the assistance of Management Information System (MIS).

B. Participants

This study focuses on the faculty members with at least one institutional research conducted for the last three years is considered as faculty researcher and those without any recorded research output from the Research and Statistics Center is considered as non-researcher. The faculty non-researchers were chosen from the roster of faculty members from different colleges and obtained to compare their faculty performance evaluation results with those of faculty researchers. Personal profile like age, gender, civil status, employment status, educational attainment and hourly rate were considered. Total population of 107 faculty researchers was used in the study while random sampling technique was used to identify the sample respondents for 109 non-researchers which number is closely the same with the other group.

C. Procedure

Documentary analysis was used as data gathering procedure for the study. The result of students'

evaluation of teaching performance from SY 2010-2011 to SY 2012-2013 was obtained from the Management Information System (MIS) of the university while the records of the research outputs of the faculty members were taken from the Research and Statistics Center.

D. Data Analysis

Frequency count and percentage were used to analyze the result of the profile variables while arithmetic mean was used to interpret the teaching performance of the faculty members. T-test was used to determine the difference on teaching performance between the non-researchers and researchers. Chi-square test was used to determine the differences between the two groups when they were grouped according to profile variables. Guttman's Coefficient of predictability was used to determine which profile variable included in the study best predicts the possibility of becoming a faculty researcher.

IV. RESULTS AND DISCUSSION

A. Relationship with the profile variable and category of faculty members

There is a difference of 9.7 percent in favor of male non-researchers while there is 8.8 percent difference in favor of female researchers. Therefore, female faculty members have significantly higher tendency of becoming researchers than males in the university since they have certain characteristics between genders in terms of writing communication skills that females have more adept than males.

There is no significant difference between the category of faculty members and their age bracket. There is a greater number of researchers in the 31-40 age bracket but lesser number in 21-30 and 41 and above age brackets compared to non-researchers. Age cannot be considered a factor in determining the possibility of faculty members in becoming a researcher compared to educational attainment because there are faculty members belong to 31 years old and above who are still pursuing their graduate studies.

Civil status is not also a factor that determines the involvement in research as denoted by the p-value of .153 which is greater than the 0.05 level of significance. There is a difference of 3.8 percent in favor of unmarried researchers but there is a difference of 2.9 percent in favor of married non-researchers wherein the differences do not signify any distinct attribute from single and married faculty members.

There is a significant relationship between non-researcher and researchers in terms of their educational attainment. There are more Bachelor's and Master's Degree holders who are non-researchers compared to Doctorate Degree holders. There is a difference of 10.2 percent among Bachelor's degree holder in favor of non-researchers but there is a little difference of 3.9 percent in favor of non-researchers who are master's degree holders while 12.1 percent difference in favor of researchers who are doctorate degree holders. The computed differences marked distinct characteristics where those faculty members who finished their graduate studies and those who still pursue advanced studies are more involved in research. Therefore, the higher the educational attainment of the faculty members, there is also a higher tendency of engaging into research activities.

There are more part-time faculty members who are not providing research output to the university with a difference of 6.3 percent compared to faculty researchers while there is 3.9 percent difference of full time faculty members in favor of the researchers. It is good to note that four (4) in every ten part time faculty members are already engaged in research activities of the university while there is only 5 out of 10 full time faculty members who were engaged in research wherein the university is expecting to have more than this figure. Therefore, employment status is not a strong factor but can still be considered to determine the research involvement of the teachers because the computed p-value of 0.079 is already closed to 0.05 level of significance. This signifies that both part-time and full-time faculty members can either contribute to the research production of the university or not.

The educational attainment of the faculty members is one of the bases of the amount of their Hourly rate but there are other factors included in the faculty classification which are not part anymore of the profile variable. The hourly rate is considered a factor that can possibly determine the research involvement of the faculty members as denoted by the computed p-value of .004 which is less than the 0.05 level of significance. There are more faculty members with hourly rate of P200-250 who are non-researchers but there are more researchers who belong to hourly rate with P251 and above. This signifies that the higher the hourly rate of the faculty, they have higher tendency in becoming faculty researchers also considering their educational qualification which is somehow related to their hourly rate.

B. Difference of Students' Evaluation on Teaching Between Researchers and Non-researchers

Faculty researchers (4.24) have significantly higher faculty performance rating in all areas of evaluation from students than non-researchers (4.10) as denoted by the computed p-value of 0.001 which is less than the 0.05 level of significance, therefore the null hypothesis is rejected. This signifies that the faculty researchers really perform better in delivering instruction and other academic related expertise to effectively transfer and share the knowledge and skills from one person to another.

The faculty researchers (4.25) obtain significantly higher teaching performance rating than non-researchers (4.10) on subject expertise specifically on stating clearly the objectives of the

lesson, presenting ideas or concepts clearly and relating subjects to other fields and life situation. Faculty researchers may have this characteristic of making clear the purpose of certain teaching and learning activity before starting doing it like what in research process of understanding the objectives to justify the most appropriate methodology and data analysis. Findings of related researches to the topic being discussed may also be shared by the teachers to relate the subject to the real life scenario. Faculty researchers may somehow adapt the same in delivering classroom instructions.

Classroom management including instruction may also be associated in any research activity because it is one of the attributes of researchers as being keen observer especially when it comes to students' behavior. Lattimer [9] found out that doing action research had helped the participants to gain greater ownership over their instructional practice in the classroom and they became more confident making instructional decisions and more independent in their lesson planning, implementation, and assessment process.

Meanwhile, understanding the individual differences of each member of the class can also be addressed through undertaking action research. Attendance and class performance can be considered as the results of the measures and assessment done inside or outside the classroom which can be utilized as important primary data for research. Uncovering the attitude of the students towards any school related factors may better explain their actions.

They obtained high performance in communication skills (4.19) with 4.27 for researchers and 4.11 for non-researchers followed by a total computed mean of 4.17 for subject expertise and instructional expertise while relational expertise obtained the least total score of 4.15. Communication skills of teachers either in oral or written should be demonstrated appropriately during the delivery of instruction. Expression of thoughts, ideas and suggestions related to the issues being discussed should always reach a certain level of expertise and professionalism.

Researchers have higher ability to identify the needs or problems of the students because it is one of the basic processes in conducting a research study. Determining what supposed to achieve is being identified first before giving anything to the receiver. Effective instruction would be supported by the result of diagnostic.

Everything happens in the classroom boils down to addressing the needs of the students. Therefore, being approachable and answerable to their needs and providing them their expectations would really demonstrate the relational expertise of the teachers. Being keen observant and sensitive to their needs would give numerous data and how to process them one by one would lead the faculty researcher to formulate research questions on how to address these effectively and efficiently. Faculty researchers who understand the problem are the teachers with longer patience.

Faculty Researchers have significantly higher teaching performance based on the students' evaluation for the last three years compared to the performance of non-researchers.

C. Predictor of Research Involvement from the Profile

Educational Attainment is considered a factor that affects the faculty members to be involved in the research activities of the university. If gender will also be considered as well as the age of the faculty members would increase the possibility of having engaged in the research undertakings. Those middle aged female master's degree holders have the higher tendency to get involved in research. The ability to write is closer to the characteristics of female than male; therefore, there are more female faculty members who were engaged into research writing than their male counterpart. Knowledge and experience in writing research is being developed during the completion of baccalaureate degrees but it is sometimes being enhanced in continuing advanced studies in the Graduate School and most of the teachers have already completed their master's degree during the middle age.

D. Predictor of Research Involvement from the Faculty Performance Evaluation

Instructional Expertise is considered as the best predictor of having possibility of becoming a researcher with combined diagnostic expertise. Knowing through assessing the existing or current knowledge of the students before providing any additional information would give the preliminary profile of a larger image of what still needs to be improved from the students. Giving them pretest and post test and analyzing the result after giving some sort of intervention measures based on the pretest to enhance the specific skills or expertise of the students is considered an action research which only needs to put into writing. Therefore, identifying the strengths and weaknesses of the students through research would provide better understanding on their individual and group differences.

V. CONCLUSION AND RECOMMENDATION

Faculty Researchers have significantly higher teaching performance based on the students' evaluation for the last three years compared to the performance of non-researchers. Female faculty members have significantly higher tendency of becoming researchers than males. Age, civil status and employment status were not factors that influence the faculty members to have an active research involvement. Faculty members with higher educational attainment at the same time with higher hourly rate have significantly higher possibility to be involved in research activities.

Since research is an important part of the faculty performance evaluation, teachers who really maintain their position within the upper 25% in the Annual Top Faculty Performer Award given by the university would pursue to accomplish researches before the evaluation period starts so that they would be given higher scores in the area of research while those teachers who wanted to be included in the reclassification to increase their hourly rate, they also tend to produce researches for them to be included in the upper 50% of the faculty performance evaluation. Some of them conduct researches for monetary reward after the completion of the research as honorarium and the chance to go abroad for research presentation.

However, those teachers who may not have any intention to be an awardee, to go abroad and be reclassified, they tend not to submit any research proposal given all the benefits provided for them by the university. Other factors may still hinder their participation like teaching work load, inadequate research writing skills, attitude or interest towards research. The orientation of research interests, however, is only the first step to becoming a researcher [6].

Teachers manage personal, workplace, and socio-cultural influences with their agency. With or without external support, teachers need to rely more on themselves to cultivate their research interest, seek professional advice and establish their own position in the academy by publishing their work [6].

The results of this study may serve as an eye-opener for faculty members who are not interested to adapt the research culture of the University. They may somehow realize the benefits and advantages of being Faculty Researcher and get involved in the research endeavors of the academic community. Male faculty members may be provided greater attention in making them interested to write research papers either for classroom use or institutional development. Bachelor's degree holders or the younger faculty members may do collaborative research to let them learn from faculty members with Master's degrees or those from the middle age group.

It is recommended that faculty members may provide necessary diagnostic test if applicable before to start giving lecture or demonstration just to determine the extent of knowledge they still need to obtain certain student outcomes. This is the initial step on gaining curiosity; learning how to identify the problems and finding solutions to make every student's life meaningful inside the classroom.

Faculty members may also be required to write books or instructional manuals as a form of research output. If they will be written their own material to be utilized in their own respective classes, mastery or the subject expertise may be fully achieved. Sending them to seminars and training workshop that would develop their skills in book or module writing may encourage them to contribute in the content of the manual to be developed in their respective discipline.

In the advent of K-12, most of the teachers from Higher Education Institutions may not be given enough teaching load compared to the previous years due to some general education subjects which will now be transferred to senior high school. This is a national dilemma of most General Education and even Professional Education Faculty members. They do not know definitely where to go but to teach in senior high school but they may not be given the same teaching rate. With that given scenario, faculty members may now have enough time due to lesser teaching load to conduct researches funded by the government or from any private agencies that provide research grants.

It is clear that strengthening the preparation of educational researchers in all fields is vital if meaningful empirical contributions to the collective knowledge of teaching and teacher education are to be made through research [10].

The findings also provide insights whether they wanted to enhance their performance and share some experiences of the research process to their students. The culture of research must start within the circle of Faculty Members before it proliferates down to the students. Research is one of the keys in achieving and sustaining excellence and quality in education. Therefore, there is no way but to adapt and make research as a way of life and a habit to contribute in the advancement of knowledge towards the achievement of the true essence of quality through continuous improvement.

The new evaluation instrument was proposed with the end view of increasing the awareness of the teachers that they will be evaluated not only based on their one-time big-time participation in research but even their little contribution and involvement related to research activity will be accounted for their evaluation. This is to concretize the areas of evaluation and defining other research related activities where the teachers might be involved that would help them improve their research performance.

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★★★

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

[1]C. BENACHAIBA, [2]B. MAZARI, [3]M. HABAB, [4]C. BENOUDJAFER, [5]N. M. TANDJAOUI

[1]Faculty of Technologies and Science, Bechar University, Algeria
[2]LDEE, Faculty of Technologies and Science, USTORAN, Algeria
E-mail: chellali@netscape.net

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.

Keywords - 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:

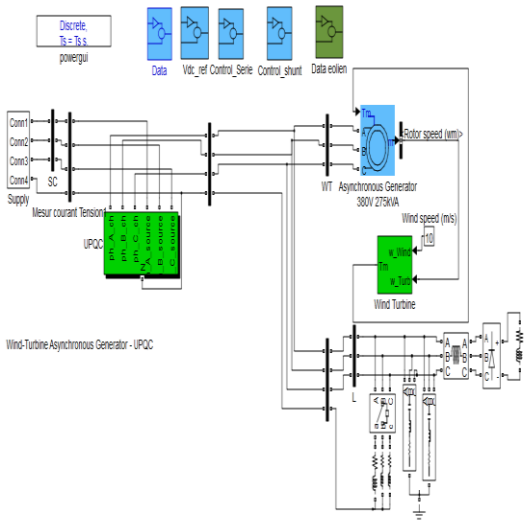

Fig. 1 The simulated system

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

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

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

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

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].

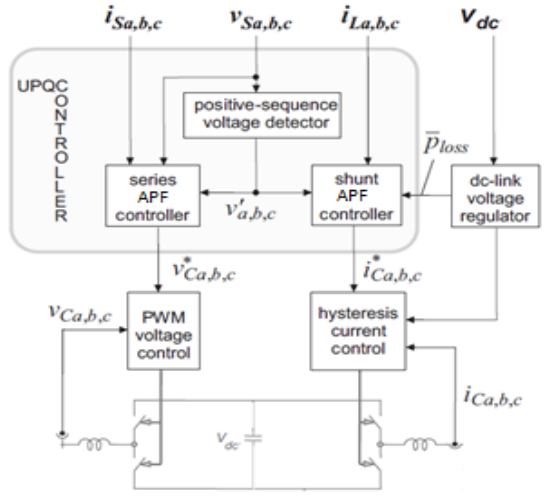

Fig. 2 Functional block diagram of a UPQC controller

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.

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

Table I: Decision table

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.

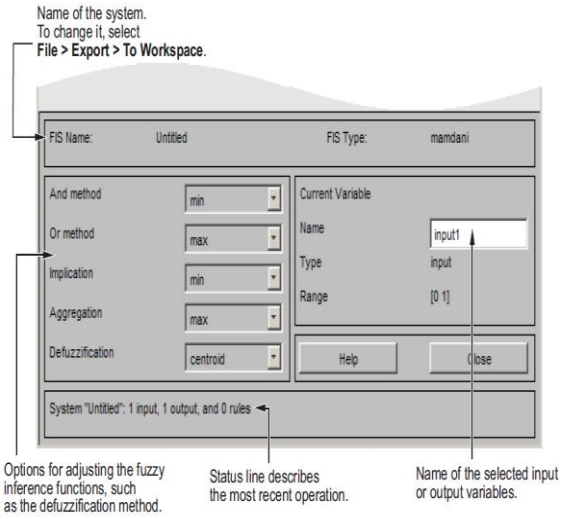

Fig. 3 FIS properties

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

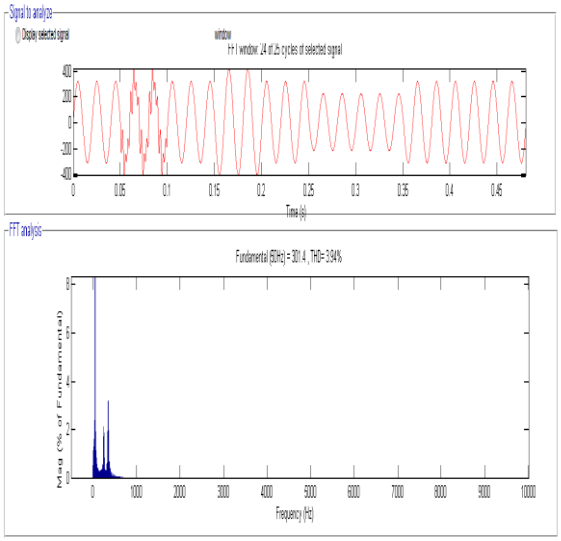

Fig. 4 Source voltage of the phase (a) and its specter

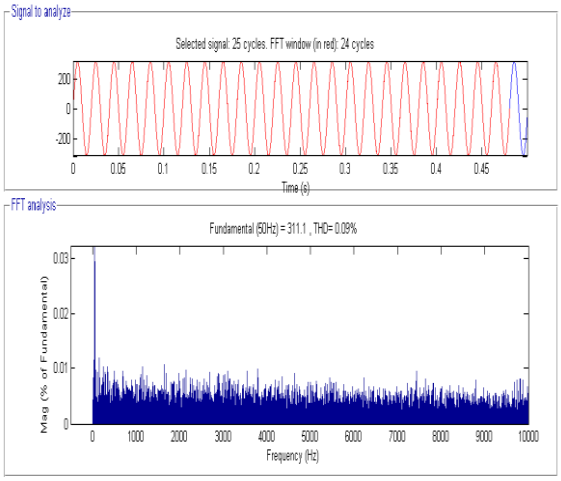

Fig. 5 Load voltage of the phase (a) and its specter

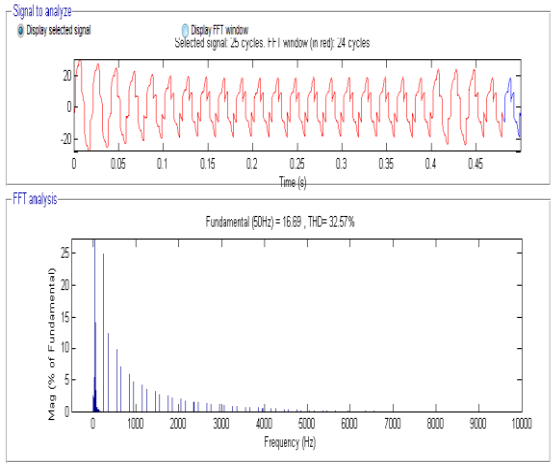

Fig. 6 Load current of the phase (a) and its specter

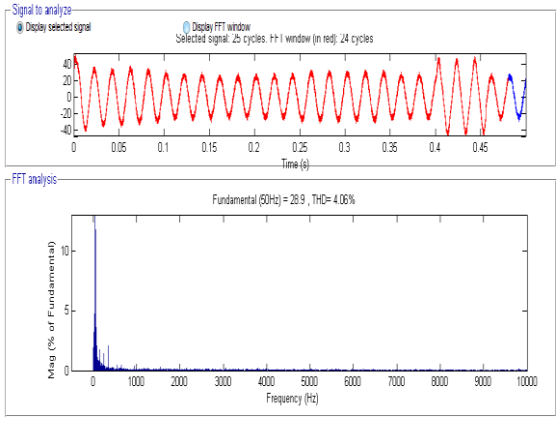

Fig. 7 Source current of the phase (a) and its specter

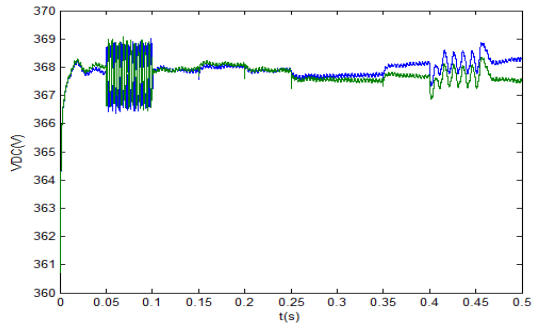

Fig. 8 DC voltage of UPQC

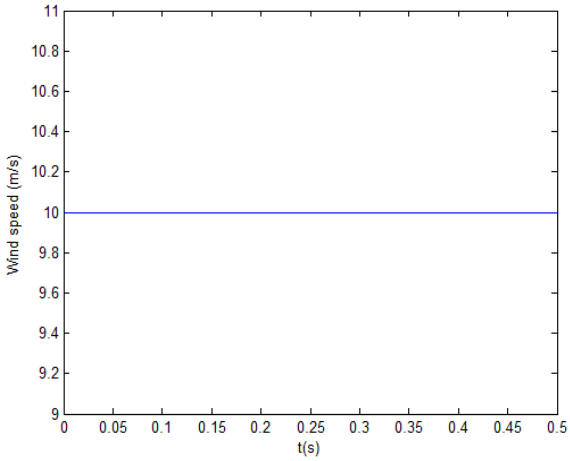

Fig. 9 Wind speed

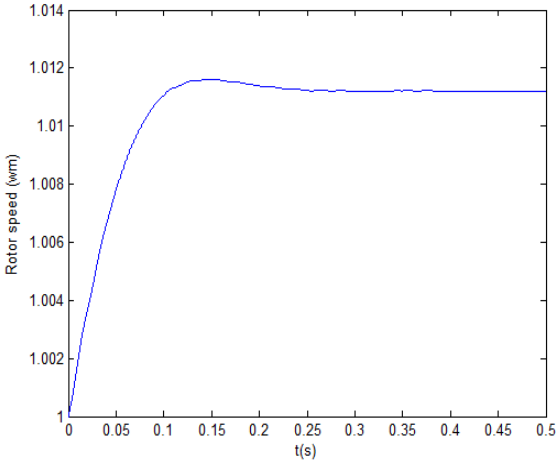

Fig. 9 Rotor speed

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

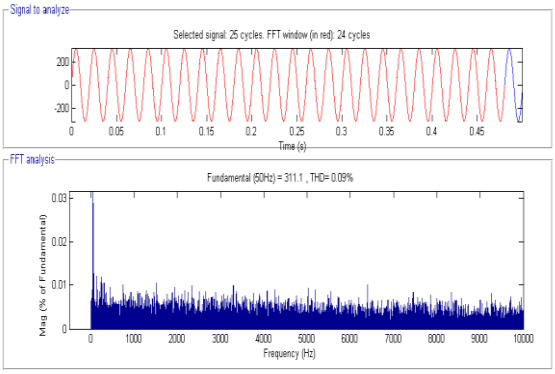

Fig. 11 Load voltage of the phase (a) and its specter

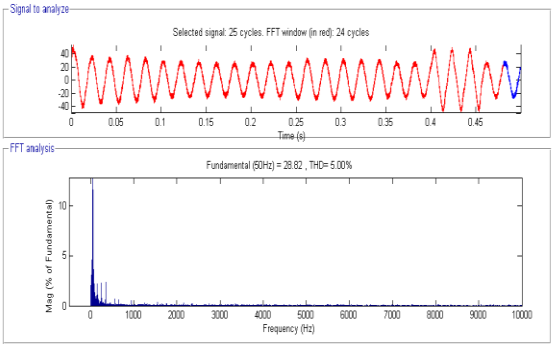

Fig. 12 Source current of the phase (a) and its specter

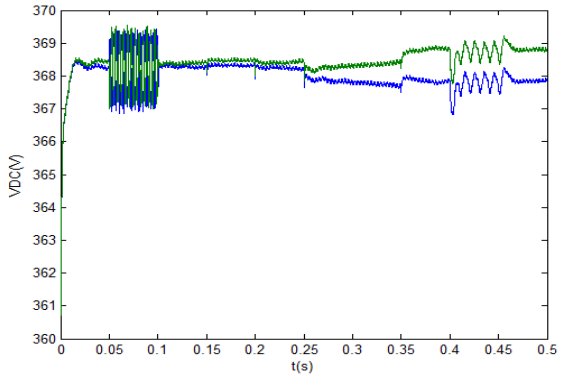

Fig. 13 DC voltage of UPQC

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

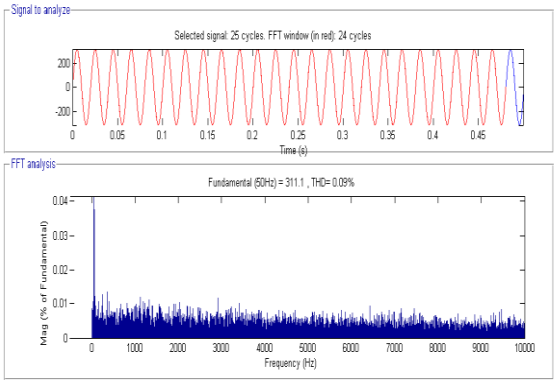

Fig. 13 Load voltage of the phase (a) and its specter

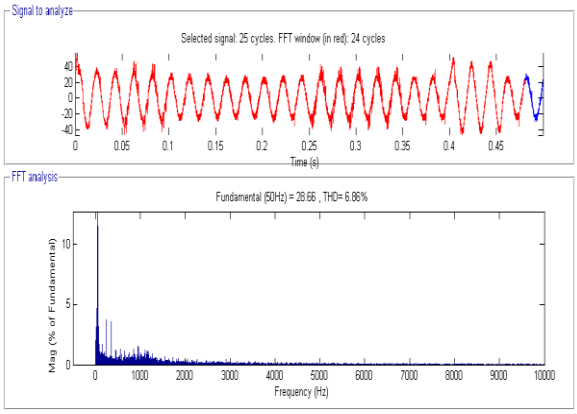

Fig. 15 Load voltage of the phase (a) and its specter

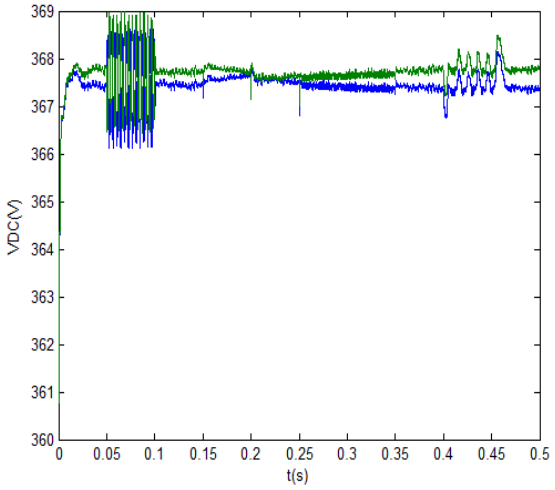

Fig. 16 DC voltage of UPQC

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.

VI. CONCLUSIONS

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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