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DESIGNING AND INVESTIGATING ERGONOMIC PATTERNS OF DEPLOYMENT IN IRAN TRACTOR COMPANY

Jaffar Beikzad, Assistant Professor of Public Management, Islamic Azad University, beikzad_jafar@yahoo.com and Amir Gharifard, MS Student of Public Management (Human Resources), Islamic Azad University, a.gharifard@yahoo.com

ABSTRACT

The main purpose of this research is recognition and precedence of elements that are efficient on the ergonomic, for designing and investigating the patterns of deployment in Tractor Company in Iran. To this end, some books and articles were reviewed and the experts' ideas were studied too. During the study, 62 efficient elements were identified. The statistic society of this research is all of employers (785 persons) of Tractor Company. The size of the statistic sample, calculated by KoKran bond, is 258 persons used from stratified random sampling. Factor analysis was utilized on two ergonomic questionnaires at Aarhus University given to statistic sample after validity, stability and assurance. Descriptive and illative statistic methods were also used for analyzing of statistics data.

Descriptive method is used for classification, precis and explanation of statistic data, and in illative level, proportion method is used for calculating size of employers' responsibility. Factor analysis technique is used by "SPSS19" software for replying identification questions and prioritizing effective elements of ergonomic establishment. LISREL software is used for endorsement of structural equation modeling. The final results showed the ergonomic establishment occurred at the acceptable level. Also 23 elements of main 62 elements, issue effective elements recognized and classified in 4 groups: person, organization, job and technology. The establishment of ergonomics method is also designed.

Keywords: Ergonomic, Human Factors Engineers, Anthropometry, 5S

TIME-DEPENDENT ARC ROUTING PROBLEM: A CASE STUDY IN TURKEY

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ABSTRACT

Many practical arc routing problems involve finding paths or tours that traverse a set of arcs in a graph. The aim of solving such problems is to determine a least cost tour which covers all or subset of arcs in a graph with or without constraints. The Chinese postman problem (CPP) is one of the most central problem in arc routing. This problem was first solved Mei-Ko Kuan, a Chinese mathematician, in 1962. In practice, there are a lot of applications such as road maintenance, waste collection, bus scheduling, electric meters reading, snow plowing, salt gritting, patrol vehicle routing application etc. Most of these studies for arc routing reported in the literature assume constant travel distance or cost. Clearly, the travel time between two nodes is ignored. In time dependent variant, the travel time is depend on the departure time of the vertex *i* within time interval. The objective is to find a route that travelling all arcs with the minimum travel times. In this study, the time-dependent mathematical model for the CPP is proposed. The proposed model is applied to a case study in Turkey and results are discussed.

Keywords: Time-Dependent Arc Routing

FOOD BEHAVIOR OF MANAGERS

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ABSTRACT

Food behavior of managers have direct impacts on their bodies, meetings results, lectures and feedbacks. Manager, men or women, must have a special charisma and fit bodies. Eating less is good in all nations. IBN SINA says that: "Low food is medicine, average is food, and high is toxin. According to the research on bosses and administrators of 50 faculties, results are surprising and troubling, only 2% of this population in working meetings use herbal tea and healthy drink and 98% use black tea. Black tea has short and long effects. For instance, short-term effects of black tea are creation of dizziness and increased gastric acid. Therefore, it is necessary to change the pattern of drinks at meeting. By combination of herbal and medicinal plants (herbal tea such as Thyme/ Cinnamon/ Rose-water/ Borage/ Citrus Aurantium/ Elettaria, and even green tea) due to the sedative neuromuscular, nerve tonic, removing bad breath, and refreshment you can use better drinks. High mental activity to a supervisor or manager increases the bodys metabolism. The brain use glucose instead of fat for energy supplies. The brain needs 1.8 calories per minute or 10.8 per hour. A smart chief or senior managers must know that an employee who drinks plenty of ice or ice water, perhaps has iron deficiency, or if eating a lot of chocolate has magnesium deficiency and eating greedily corn probably has deficiency of sodium. Talking on the phone 39 calories, attending office meeting (including talking and eating at meeting) 59 calories, and also secretary director approximately 34 calories in an hour, for paperwork 110 calories burn for a normal person. Furthermore, managers must chew more their food to control stress levies during the day.

Keywords: Food behavior, Herbal tea, Smart Chief

A MODEL OF REVERSE LOGISTICS NETWORK OPTIMIZATION IN CELL PHONES INDUSTRY IN IRAN

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ABSTRACT

In recent years with the advent of electronic devices such as cell phones and continuously updated communications equipment, electronic waste is one of the most vulnerable challenges on environment. We believe in this paper is to examine the economic and environmental aspects of returning mobile phones into life cycle to reuse them. The overall goals of plan includes the reuse of cell phones (at the end of life) by collection centers, avoiding waste further useful materials such as gold, silver used in mobile phones and during this process (reverse logistics network) will create employment and entrepreneurship. This paper presents the design of a reverse logistic network for End-of-Life cell phones in Iran. The deliverables of the proposed mathematical model includes: routing vehicles to collect delivered cell phones, allocating of fixed and operational costs to collection centers, and considering the transportation cost of returning processes.

Keywords: Reverse Logistics Network, End-of-Life, Transportation Costs, Sustainable Environment

THE MOTIVATIONAL CHALLENGES OF ENGINEERS IN OLD INDUSTRIES: A CASE OF IRAN

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ABSTRACT

After the 1979 Islamic Revolution in Iran, the number of engineers has sharply increased in line with the policy of independence so that the country would rely on its own domestic engineers among many other technicians and practitioners. Thus, finding a job has been challenging for Iranian engineers since the number of engineers outweighs that of the available positions. On the other hand, those who are employed mostly in old industries find the jobs monotonous, boring and at times depressing. That is because such old industries have not been modified well. Therefore, this study tries to investigate the motivational factors among Iranian engineers in 5 different provinces of Iran. The data comes from semi-structured interviews with 50 engineers. The results of the study revealed that most of the interviews feel demotivated because of (a) low income, (b) uncompetitive job atmosphere and (c) routine tasks. Thus, the authors argue that company owners as well as officials should focus on the needs of the labor force to come up with more productive factories. At the end, some recommendations are made.

Keywords: Motivation, Engineers, Job Satisfaction

INDUSTRIES IN DEVELOPING COUNTRIES AS THE MAIN SOURCE OF POLLUTION: A CASE OF IRAN

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ABSTRACT

Pollution is one of the biggest issues that many countries are dealing with these days. In developing countries, however, the problem is even worse as the economy is not strong enough to provide financial resources to overcome this important environmental crisis. Therefore, most of the developing countries are having difficult time regarding pollution in general and air pollution in particular. The main source of air pollution in developing countries is the old industries. Unfortunately, such industries do not care about upgrading their facilities and moving toward having more green equipment. Thus, this study tries to investigate the challenges that environmental agencies have when they are dealing with old industries which produce a lot of pollutions. To this end, 20 semi-structured interviews were conducted by head of such organizations in four different cities in Iran. Similarly, 10 CEO of old industries were interviewed too. The results of the study revealed that financial issues are the biggest challenge that such companies have which prevent them from upgrading their facilities. Also, lack of education regarding the consequences of air pollution created by such factories was another finding of this study. Therefore, the author argues that how private and state-run sectors can help old industries to both receive enough education and funding so that they can work together to solve this issue in developing countries.

Keywords: Pollution, industries, developing countries.

PREDICTIVE MODELING OF AIRCRAFT FLIGHT DELAY

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ABSTRACT

Flight delay has been one of the major issues in the airline industry. A study by Frankfurt-based consulting company "Aviation Experts", presented that costs of $25 billion were incurred in 2014 due to flight delays worldwide. Domestic flight delays have an indirect negative impact on the US economy, reducing the US gross domestic product (GDP) by $4 billion. This project investigates the significant factors responsible for flight delays in the year 2016. The data set extracted from Bureau of Transportation Statistics (BTS) containing one million instances each having 8 attributes is used for the analysis. We describe a predictive modeling engine using machine learning techniques and statistical models to identify delays in advance. The data set is cleaned and imputed. Techniques such as decision trees, random forest and multiple linear regression are used. We attempt to put forth a solution to the delay losses incurred by the airline industry by identifying the critical parameters responsible for flight delay. Not only airlines incur a huge amount of cost per year, airport authorities and its operations are also affected adversely. This leads to inconvenience to the travelers. Predictive modeling developed in this study can lead to better management decisions allowing for effective flight scheduling. In addition, the highlighted significant factors can give an insight into the root cause of aircraft delays.

Keywords: - Decision Trees, Machine learning techniques, Multiple linear regression, Predictive modeling, Random Forest, Flight delay.

I. Introduction

Flight delay has been the subject of several studies in recent years. With the increase in the demand for air travel, effects of flight delay have been increasing. The Federal Aviation Administration (FAA) estimates that commercial aviation delays, cost airlines more than $3 billion per year (Nicholas G. Rupp, 2007). According to Bureau of Transportation Statistics, the total number of arrival delay in 2016 were 860,646. Impacts of flight delay in future are likely to get worse due to an increase in the air traffic congestion, growth of commercial airlines and increase in the number of passengers per year. While air traffic delays are likely to persist in future due to unavoidable factors such as weather and unpredictable flight maintenance, we seek to identify

operational critical factors responsible for delays and create a predictive algorithm to forecast flight delay.

There have been many predictive modeling and simulation attempts to forecast flight delays. Juan Jose Rebollo and Hamsa Balakrishnan (2014), summarized the results of different classification and regression models. The study reveals that amongst all the methods used on 100 origin-destination pairs (OD pairs), random forest was found to have superior performance. However, the predictability might vary due to factors such as forecast horizon and the number of OD pairs. Dominique Burgauer and Jacob Peters (2000) develop a multiple regression model and show that factors such as distance, day and scheduled departure play a significant role in flight delay. While the model gives the significant factors, the prediction accuracy was found to be poor. In addition, the model is limited to only one flight route, namely Los Angeles to San Francisco.

Q. L. Qin and H. Yu (2014) investigate the overall airline data. A comparison of the K means clustering and Fourier fit model yielded that Fourier fit model gave a thorough analysis of the JFK airport in different aspects and could predict the delay trend with a high precision. It is found that the two methods used work well for a single airport and are not suitable for multiple airport analysis.

From the search of literature,[1-5] one may conclude that, to better predict flight delays irrespective of the route, number of days and forecasting horizon, operational factors must be modeled. The objective of this paper is to analyze the on-time performance of domestic flights for the year 2016 and develop a predictive model to forecast flight delay. Background is described in section 2, Data description and method used are in section 3. Finally, the conclusions are provided in section 4.

II. Background

A. Multiple Linear Regression (MLR)

An MLR is a straight forward approach for predicting a quantitative response Y based on multiple predictor variables. The number of predictor variables should be two or more. This model assumes that there is approximately linear relation between X and Y. Linear relation meaning, as X increases/decreases, Y also increases/decrease. Mathematically we can write a multilinear relationship as

$$y = \beta_0 + \sum_{i=1}^{m} \beta_i x_1 + \varepsilon \qquad (2.1)$$

In equation 2.1, β0 is the intercept and β1…. βm are the constants that represent the slope of the respective variables. They are described as the mean change in Y when all other variables are constant. Many time, it is the case that the predictor variable are dependent on each other i.e. the effect of x_i on y depends on the value of x_j. Now in this case the simple model as in equation 2.1 is not sufficient. Terms that model two-factor interactions must be introduced into the equation.

The linear developed in this project can be represented as a sum of k terms expressed in a generic form as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_{i(k-1)} x_{i(k-1)} + \varepsilon \qquad (2.2)$$

where each x_i^j is a distinct term from the complete model. The collection of the chosen terms is referred as model terms.

B. Decision Trees (DT)

Decision trees involve stratifying or segmenting the predictor space into several simple regions. To make a prediction for a given observation, we typically use the mean or the mode of the training observation in the region to which it belongs. Decision trees are simple and easy to interpret. In addition, they can be applied to both regression and classification problems. A DT is composed of nodes where the topmost node is the root of the tree. Each node is split into two further nodes and the nodes that cannot be split further are called the terminal or leaf nodes. DT's follow a top-down greedy approach. It is "greedy" because, while splitting, the best split is made at the present node rather than looking forward and picking a split leading to a better tree. Due to this approach pruning must done, once the tree is formed. An unpruned tree might suffer from overfitting problem and providing extremely good accuracy when compared to other models.

The algorithm of decision tree recursively subdivides the training set into homogenous groups. These groups are created using discriminating variables. This procedure is repeated until all the data has been divided to belong to a pure subset.

C. Random Forest Trees (RFT)

Random Forest is a method for classification and regression which was introduced by Breiman and Cutler (2001). RF's are an extension of the decision trees. It consists of a collection of decision trees that grow in parallel to each other. This helps in reduction of variance in the model.

In other word, RFT algorithm averages a set of observations to reduce the overall variance. In RF regression, an ensemble of regression trees is grown from separate bootstrap samples of the training data using the CART algorithm.[7] In the random forest algorithm, the trees are not pruned back and the descriptor selected for branch splitting is selected from a randomly selected of predetermined size.

D. Mean Squared Error (MSE)

The mean squared error or mean squared deviation (MSD) measures the average of the squares of the errors or deviations—that is, the difference between the estimator and what is estimated. This difference between the estimator and the estimated value is seen because of the randomness in the data or to put in other words, it is because the estimator does not account for all the information which would result in a more accurate estimate. It can be stated that the MSE measures the quality of the estimator or the predictor. The more the value of MSE closer to zero, the better the quality of estimator. Although MSE is a measure of quality of estimator, taking the root of the MSE give root mean squared error. It basically measures the standard deviation.

If $\hat{y}_i$ is the predicted value and y_i is the response value, then the MSE of the predictor can be estimated by

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2 \qquad (2.3)$$

In the above equation $\hat{y}_i$ in most cases is a vector of N predictions and y_i is a vector of observed values or vector of response variable.

III. Data Description and Methodologies

A. Data source

The results presented in the study were obtained using the data from the BTS. The period for which we analyze the data is from beginning of January 2016 to December 2016. BTS data base provides detailed data for individual domestic flights. The fields used for the analysis of the data are Departure delay, Taxi in, Taxi out, Carrier delay, Security delay, Weather delay, Late aircraft delay, Distance and National air system delay.

The data is cleaned and processed to obtain a more robust delay estimate. Imputations using additive regression, bootstrapping, and predictive mean matching were done to account for the

missing values. "Hmisc" package in R studio was used to run the imputations. The raw data set spanned for 1 million observations each having 8 attributes. Since the analysis is focused on flight delay only nine variables were selected for analysis. Following is the table describing all the variables:

Sr. no.	Attribute	Description
1.	Departure Delay	Difference in minutes between scheduled and actual departure time. Early departures show negative numbers.
2.	Distance	Distance between airports (miles)
3.	Taxi In	Taxi in time, in minutes
4.	Taxi Out	Taxi out time, in minutes
5.	Carrier Delay	Aircraft carrier Delay, in minutes
6.	Weather delay	Weather Delay, in minutes
7.	NAS Delay	National air system Delay, in minutes
8.	Security Delay	Security delay, in minutes
9.	Late Aircraft Delay	Late aircraft delay, in minutes

B. Data Analysis

Preliminary analysis

Figure-1 represents the Scatterplot matrix of all variables. It is observed that departure delay has linear relation with Carrier Delay, Weather Delay, NAS delay and late aircraft delay. Since we have a somewhat linear relation with four variables, we can use multiple linear regression on the data. The diagonal of the plot represents all the variables. A slight hint of multicollinearity between variables can be gained from the plot. The relation between Taxi out and NAS delay can have multicollinearity problems. However further tests should be carried out to confirm the same.

Also, we see that the distribution of all the variables is given in the diagonal of the plot. The response variable is highly skewed to the left. This can lead to the violation of the normality rule after the basic regression model is formed.

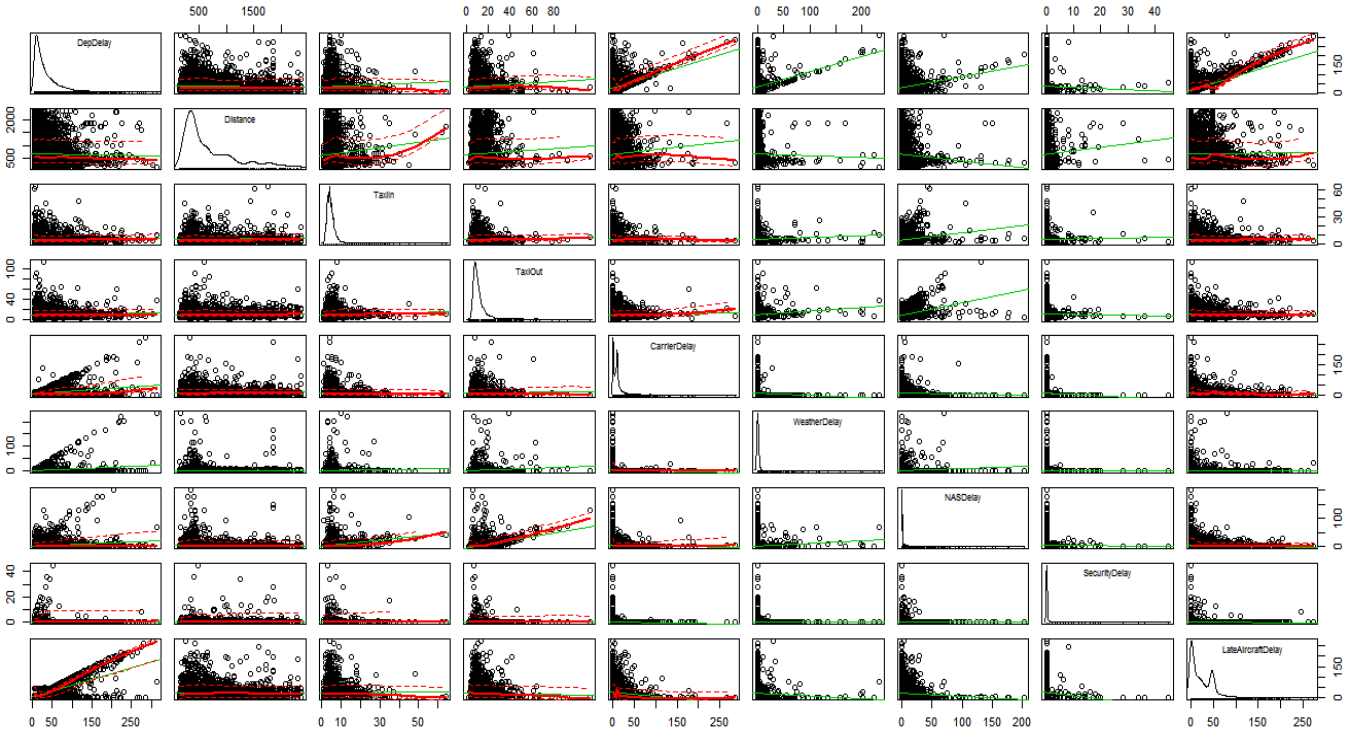


Figure-1

Scatter plot matrix of all the variables

<u>The Predictor Plot Correlation</u>

The predictor plot gives the Pearson's constant for the variables. Pearson's constant is another way of detecting multicollinearity within the variables. In this study, a value greater than 0.5 is considered to have serious multicollinearity problems. But it is observed that no Pearson's constant exceeds this value, suggesting all the variables are independent. It is also observed that linear relation between departure delay and carrier delay exists.

	DepDelay	Distance	TaxiIn	TaxiOut	CarrierDelay	WeatherDelay	NASDelay	SecurityDelay	LateAircraftDelay
DepDelay	1	-0.008444647	0.074082215	0.077763781	0.526808035	0.248528239	0.300320601	-0.016650507	0.467740449
Distance	-0.008444647	1	0.07150836	0.07118311	0.014189887	-0.027744382	-0.001452409	0.00085407	0.023294442
TaxiIn	0.074082214	0.07150836	1	0.066415487	0.008970034	0.039859885	0.235657187	-0.001850089	0.000618343
TaxiOut	0.077763781	0.07118311	0.066415487	1	0.010281969	0.092641674	0.447768289	-0.009421997	-0.02913716
CarrierDelay	0.526808035	0.014189887	0.008970034	0.010281969	1	-0.050103383	-0.076364223	-0.025475308	-0.133874366
WeatherDelay	0.248528239	-0.027744382	0.039859885	0.092641674	-0.050103383	1	0.018261117	-0.006999512	-0.050246439
NASDelay	0.300320601	-0.001452409	0.235657187	0.447768289	-0.076364223	0.018261117	1	-0.017283281	-0.082314787
SecurityDelay	-0.016650507	0.00085407	-0.001850089	-0.009421997	-0.025475308	-0.006999512	-0.017283281	1	-0.042449764
LateAircraftDelay	0.467740449	0.023294442	0.000618343	-0.02913716	-0.133874366	-0.050246439	-0.082314787	-0.042449764	1

Multiple Regression Model

An MLR was developed on the training data set. It was observed that all the variables were significant with an r-square of 0.84. A stepwise regression was applied after the main model was developed. The stepwise regression gave same results as the original model. The RMSE for the MLR model is 21.2 minutes. The MLR equation is given below.

*DepDelay = 10.57 - (7.95) * (10^-4)*Distance - 0.4392*TaxiIn - 0.5579*TaxiOut + 0.9791*CarrierDelay + 0.991*WeatherDelay + 0.9088*NASDelay + 1.119*SecurityDelay + 0.8814*LateAircraftDelay*

After the main MLR was formed, further analysis like residual analysis, normality test and constant variance test were conducted.

a) *Residual analysis :-* Following is the plot for residual values versus fitted delay values. In the residual plot, the values are centered at 0 and the red line indicates the trend of the residuals. Some points are scattered in the negative and the positive region at the beginning going from left to right. Most of them come in the horizontal band centered around 0. In addition, three outliers are observed in the plot. However before conforming that those observations are outliers we need to do further tests. This suggests that the MLR model is appropriate.

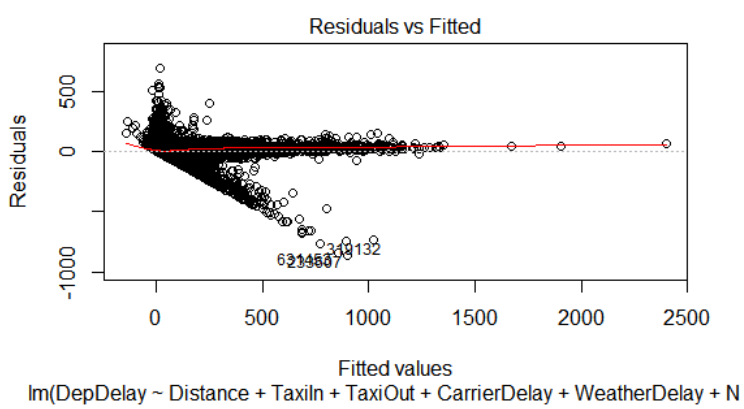
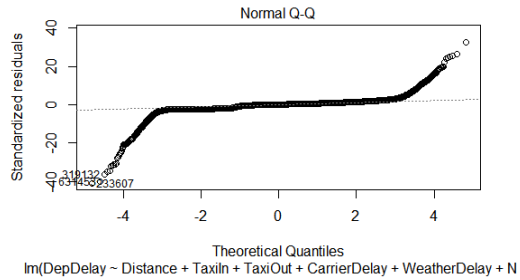


Figure-2

b) *Test for Normality:-* Figure-3 shows the normal probability plot. We see that it is heavily tailed and can conclude that the normality rule is violated.



The studentized residual tend to go to the negative side on the left of the plot and to the positive side to the right of the plot. We see that as the normal score increase as the studentized residuals increase. But this is not in a linear fashion. This suggests that there is no normality between the plotted residuals and the expected values.

Figure-3

c) *Variance Inflation Factor (VIF):-* Following is a table of all the VIF's for all the parameters.

Attributes	**VIF's**
Distance	1.014873
Taxi In	1.081754
Taxi Out	1.420426
Carrier Delay	1.033722
Weather Delay	1.077174
NASDelay	1.345210
Security Delay	1.011125
LateAircraftDelay	1.034205

VIF is a multicollinearity test to determine how each variable is correlated to another variable. The idea is, all variables should be independent to each other. However, almost all data in real world are affected by other variables. VIF test helps to identify serious multicollinearity problems.

The decision criteria is, a serious multicollinearity problems occurs when VIF value is greater than 5. In the above table, we see that all the values are seen to be around one. This suggests that there are is no multicollinearity between any variables.

d) *Outliers:-* For this test, we must first find the X and the Y outliers. The X outliers are identified sing leverage values (hii) and then they are compared to the average leverage values 2*(p/n). Where 'p' is the number of predictor variables and 'n' is the number of observations. We know that we consider an X value as an outlier if the (hii)> 2*(p/n). Following is the table of all the X and Y outliers.

Observation no.	R-student	Unadjusted p-value	Bonferroni p
233607	-41.01559	0.00E+00	0.00E+00
631453	-40.0481	0.00E+00	0.00E+00
319132	-36.28399	5.49E-288	3.72E-282
619881	-35.00319	3.50E-268	2.37E-262
520602	-34.65413	6.59E-263	4.47E-257
646455	32.81721	5.14E-236	3.48E-230
481652	-31.97198	3.93E-224	2.67E-218
615562	-31.72412	1.05E-220	7.12E-215
491093	-31.23493	5.08E-214	3.44E-208
58303	-31.06832	9.11E-212	6.17E-206

The Y outliers are found using the following formula. We identify them using studentized deleted residuals.

$$t_i = \frac{d_i}{\sqrt{MSE_i(1-h_{ii})}} = e_i\sqrt{\frac{n-p-1}{SSE(1-h_{ii})-e_i^2}}..$$

The decision criteria is when $|t_i| > t\,(1-\alpha/2n,\ n-p-1)$, it is considered to be y outlier

e) *Influential Observations:-* Following is cook's distance graph with respect to the number of observations.

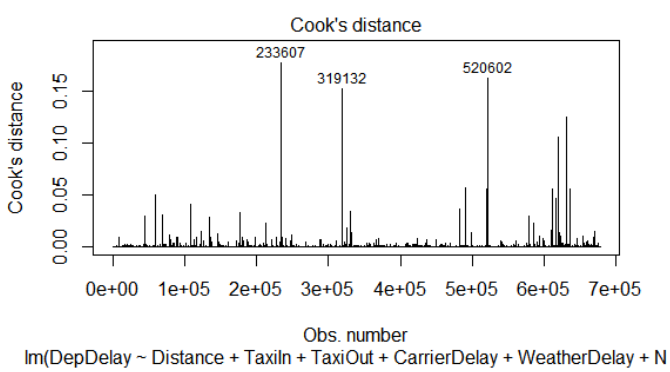


Figure-4

Cook's distance

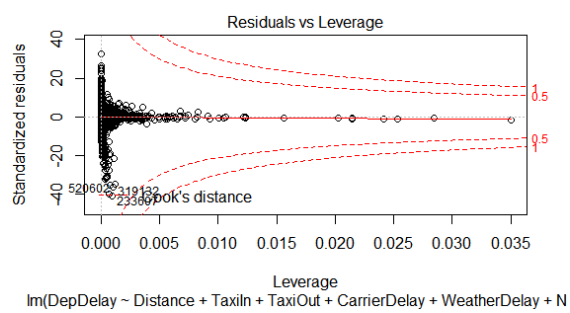


Figure-5

Leverage graph

Here we see that observations 233607,319132,520602 are considered as influential observations. The observation 233607 is also an outlier as seen in Bonferroni test and residual graph. Influential observations are of a concern because they might tend to deviate the fitted line towards them. The second graph shows us the leverage values of the outliers. Leverage is defined

as the distance of a point from the total mass of all the points. A normal thumb rule is that, if the cooks distance is greater than 1, that point is influential. But R's default algorithm considers points with a distance greater than 0.5 and classifies those points as outliers.

Once the outliers are detected, we must remove them due to their effect on the fit of the model. In this study, these outliers are excluded from the data set for further analysis.

Decision Tree

Since the data was not exactly linear, a DT model was developed to analyze the data. The parameters of the model are chosen such that the error is minimal. Following are the graphs showing the r-square and relative error with respect to the number of splits.

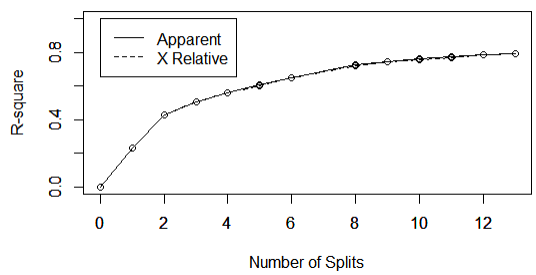


Figure-6

R- square Vs number of splits

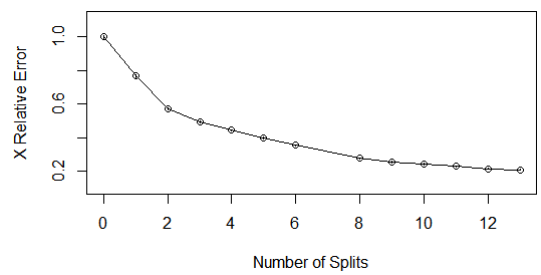


Figure-7

Relative error Vs number of splits

It is seen that the r-square does not increase significantly after 10 splits. Considering the cross validation error graph, the tree was pruned to 10 trees from an original size of 14. The splitting variables or the significant variable are found to be late aircraft delay, Carrier delay, weather delay and NAS delay. The package "tree" was used to build the decision tree model. All the parameters were kept at the default values. The RMSE for the decision tree model is 26.5 minutes.

Random Forest

Random to forest trees were developed for the data. Following table explains the parameters for the RF model:

RF Parameters	**Values**
Number of Trees	500
Independent variable	8
Number of predictions	290247
Mtry (no. of split at each node)	2

R-square	0.94
Split Rule	Variance

It is seen that a total of 500 trees were constructed by the RF algorithm. This number is the default number in the "ranger" package. The r-square is found to be 0.94. As we know RFT's provides an advantage over decision trees, bootstrapping and bagging, construction a large number of decision tress can lead to an improvement in prediction results. Default values were used for parameters such as number of trees, mtry, variable importance, minimum node size and sample with replacement. The prediction error was found to be 153.94 and the RMSE for the RFT model is 12.5 minutes.

IV. Conclusions

This study develops a predictive model to forecast flight delays. Models based on multiple linear regression, decision trees and random forest algorithms are created and tested in R-studio software. Results show that Random forest model outperforms other two models based on the evaluation criteria. In addition, the study also sheds light on the significant factors responsible for departure delay. The splitting variables or the significant variable are found to be late aircraft delay, Carrier delay, weather delay and NAS delay which have the most effect on departure delay.

Although the model gives a very good prediction accuracy, more variable can be used to develop a predictive model. For example, as we have seen weather delay is one of the significant factors causing departure delay, Weather data can be extracted and used to develop a predictive model for flight delay. The future scope of this study involves various approaches that can be used to analyze the data. Principal component analysis or transformation can be done to uncover hidden relations between variables. In addition, since the data is not exactly linear, artificial neural networks or Support vector machines can be used to analyze the effect of various variables on flight delay.

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ASSESSING THE USE OF SOCIAL MEDIA FOR RECRUITING STUDENT-ATHLETES AT AN INSTITUTION OF HIGHER ED IN SOUTH TEXAS

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ABSTRACT

The number of active users of social media continues increasing on a daily basis, having more people using these sites to stay connected with family and friends. According to Rahmati, 98 percent of American universities have presence on Facebook, and 84 percent are active on Twitter while 72 percent of incoming high school seniors report researching their prospective colleges on a social media sites. Thus, athletic departments are quickly realizing the impact that social media can have in the recruiting process. A well-developed social media strategy can enable coaches to more easily promote their schools, athletic departments, and specific programs to potential recruits, thus allowing them to find athletes that can satisfy their recruiting expectations, needs, and requirements. This research is based on a survey given the coaches and administrative personnel within the athletic department at an institution of Higher Education in south Texas. The purpose of this research was to investigate the social media usage, strategy and proliferation of this media for the recruitment of potential athletes and their knowledge of the regulations established by the NCAA for social media use.

Introduction

The current trend of social media usage in the process of recruiting student athletes, is becoming one of the largest tools in finding, and signing prospective student athletes into collegiate level sports. The increased use of social media by student athletes is a key factor changing the recruiting process and coaches are trying to keep up with the new trend of recruiting athletes using social media. According to DeShazo, 80% of the interviewed athletes (total number of 927 student athletes) had a social media account (DeShazo, 2015).

Social media has forever transformed how recruiting works. For years, the recruiting process started with the high school coach. With the rapid increase of social media usage, the recruiting process is able to start much earlier, and much quicker. For coaches social media serves as an additional channel for contacting, recruiting, and gathering information about players. For student athletes, on the other hand, social media can be a means of getting recruited, by elevating their social profile through interactions with local fans, students, coaches, and other recruits, in

ways unimaginable just a few short years ago (Rahmati, 2016). Thus, social media can provide connections among coaches, staff, and prospects in an easy and affordable manner. However, if handled incorrectly, institutions can face serious penalties and sanctions from the National Collegiate Athletic Association (NCAA), the member-led organization dedicated to the well-being and lifelong success of college athletes.

"Nothing has impacted recruiting more in the last 20 years than social media," Nebraska director of player personnel Ryan Gunderson said (Gunderson, 2016). Whether it's through Facebook, Instagram, Snapchat, Twitter or some other app, social media has invaded every aspect of the recruiting process. Social media has many benefits when it comes to the recruiting process. It provides incredible reach and opportunity to coaches, athletic departments and their recruiting efforts. Some ways that athletic departments can immediately begin realizing the benefits of social media are (Rahmati, 2016):

- Program awareness – social media provides access that cannot be captured through the university website, e-mails, or brochures.
- Instant Connections – coaches are able to simply connect with a recruit on any social media platform and start engaging into a conversation.
- Recruiting insights – coaches are able to monitor every word that the recruit shares on social media. This helps coaches learn more about their potential recruit.
- Competitive intelligence – coaches and athletic departments have the ability to easily identify social conversations around top prospects in order to see how competing schools are interacting with prospects.
- Compliance – the current NCAA regulations about social media usage are much less restrictive than traditional recruiting guidelines.
- Free – this is one of the most important benefits of social media. Social media is free making the recruiting process very convenient. Athletic departments are able to save considerable amounts of money using social media as a form of recruiting.

It should be noted that coaches around the country are becoming frequent users of social media in the recruitment process. "If you want to be a good recruiter in today's college football, you have to be on social media," Iowa State director of scouting John Kuceyeski said (Kuceyeski, 2016). "If you're not doing it, you're going to get beat by somebody that's doing it. You have to be out there. You have to be different. You have to be completely visible and be accessible, and the

best way to do that in today's recruiting world is through social media." "We're using social media to rebrand Iowa State football," Campbell said. "We have to brand to recruits what's our style of play, who our coaches are, and what's the culture we're trying to put in place here. We're trying to create a culture that young people say, 'Man, I want to be a part of something like that,' or 'Hey, I'm interested in going to see what's going on,' and 'Why is that place special right now? (Campbell, 2016). Coaches state that social media help them advertise their school and athletic programs in order to attract prospects easily. Social media helps both the potential student athlete and the coach to learn more about one another and see if they would be a good fit.

Social media can be very beneficial to coaches, but it can be detrimental for potential student athletes. Many recruits seem to forget that their profiles are public and accessible not just to their friends but also to the coaches. Coaches can easily see what the recruits are posting, re-tweeting , their favorites, likes and share, and in many cases they can also see what a prospect's inner circle of friends are doing (Rahmati, 2016). Social media might seem harmless and fun, but it has a lot of influence on an athlete's future. There are numerous examples of recruits having scholarships pulled or being completely dropped because of social media entanglements. The University of Houston head football coach, Tony Levine, said in a 2014 interview that he has dropped three recruits from the 2014 class due to inappropriate remarks posted on social media. Levine stated: "I think it gives you a little insight now into the young man you are talking about becoming a part of your program (Levine, 2014)." In April 2014, Penn State offensive line coach Herb Hand issued a tweet indicating that a prospect had been dropped from recruitment due to his social media presence, he stated that via social media, he had seen the prospect's genuine character (Associated Press, 2014). Their statements suggests that increasingly, college coaches and athletic department personnel are using social media to evaluate a future student-athlete's character (Associated Press, 2014). One ill-conceived tweet, post, or comment can result in the loss of a scholarship and future career opportunities with the decision-making responsibility resting in the hands of athletic department administrators or coaches (DiVeronica, 2014). Most programs don't have the recruiting budgets and resources that major Division One institutions have. Therefore, smaller schools are doing as much research on recruits as possible before they commit to offering a scholarship. There is no room for error, so "what better place to see what a person is really like than on their social media account," Enright, CEO of Recruit Look said (Enright, 2014).

Methodology

Thus, marketing and social media have both a huge impact on every aspect of people's lives. This also implies to the NCAA programs, and the process of recruiting potential student athletes. As mentioned earlier, it is already known that social media's impact on people's lives grows every day. This means that it is very important to find out what recruiting technique coaches are going to consider. This is especially crucial to programs with smaller budgets, since recruiting with the help of online marketing can save them a lot of money knowing the fact that almost every type of social media is free.

For the purpose of this study, a survey was considered as the appropriate tool to analyze the use of social media as a recruiting tool used by current coaches. The survey was given to 31 coaches at the collegiate level programs in the institution selected for this study. The survey included 8 questions about social media related to the process of recruiting, methods of searching for potential athletes, benefits of using social media in the recruiting process, and how social media has changed the way recruiting is conducted. The recruiting survey was handed to the selected group of coaches as a hard copy and then turned in. The names of the coaches selected was obtained from the official athletics website posted online. An Informed consent document was created and it was attached to each survey given to coaches. An e-mail was sent to the Athletic Director of the program in which permission to hand out the survey to coaches was requested. After approval, the paper survey was left in the offices of the coaches on campus. No identifiable information was requested in the survey. The Information obtained from the surveys was stored in computer files protected with a password. This consent form was filed securely in an official area. The questions asked in the survey revolved around the preferred social media venue for recruitment purposes, how these tools are used, and the level of knowledge about the regulations about social media usage stipulated by National Collegiate Athletic Association (NCAA). The survey also asked for their input about how they think the institution could help them in their recruitment efforts using social media.

Results

The collected data from the 31 surveys was analyzed using the Excel software. The data analysis showed that 94 percent of the institution's coaches use social media as a way to connect with potential student athletes. Facebook and Twitter were the most frequently used social media websites by coaches. Twitter was considered the most frequently used website with 52% of the coaches using it, while Facebook was favored by 48%. Fourty one percent of the coaches see social media as a way of getting to know potential student athletes, 28% see it as a way to promote the team, 17% use social media as a way to offer scholarships, and 14% use social media to promote the school's environment. As previously stated, several coaches have rejected potential athletes due to their activity in social media. Coaches at the institution stated that 62% of them have encountered the use of inappropriate language by potential student athletes on social media, 31% have witnessed pictures showing the use of alcohol and drugs, and 7% have witnessed statements that could be deemed as discriminatory. Even though 94% of the coaches stated that they are aware of the current NCAA regulations about social media usage, 81% of the coaches failed to provide the correct answer to the question regarding the number of NCAA regulations applicable to this area.

Being aware of current NCAA regulations is very important for coaches at collegiate level. Since the analysis showed that 81% of the coaches at the institution are not fully aware of the existing regulations regarding social media usage, it is pivotal to raise awareness of what those privileges entail. Coaches were asked about diverse forms they would like to receive more education about social media use in the recruitment process. The survey showed that 58% of the respondents stated that they would like to receive training in order to feel more confident when they take the test, 32% of them would prefer handouts containing the relevant regulations and necessary information. Only 10% of the coaches stated that they would feel confident with their knowledge by simply watching a Power Point presentation explaining the regulations that are most relevant and that they should be cognizant of. Coaches are tested on a yearly basis, however social media use does not seem to be included in the examination.

Conclusion

Some applicable solutions to increment the knowledge of NACC regulations among coaches would be to include such questions in their yearly examination. Increased knowledge

during the testing process would facilitate the coaches' efforts in the recruitment process, without violating any possible regulations. Social media can be used as a tool to raise program awareness, make instant connections, learn more about potential student athletes, and most importantly, it can be done at no additional cost. Social media is the way several people communicate nowadays, specially the youth targeted by recruiters. This study showed that 94% of the coaches at the institution use social media as a way to communicate with potential athletes. For coaches and athletic departments, the key is finding the right strategy for targeting suitable recruits. If the strategy is using social media, the coaches need to abide with all the current regulations and be up-to-date as these regulations may change overtime. Thus, an important finding of this study was that coaches at this institution are not fully aware of the current social media regulations. This can lead to serious problems not just for the Athletic Department, but also for the entire institution since their lack of awareness may lead to undesired violations of NCAA rules. This potential problem can be solved by three applicable solutions. One of the proposed solutions is to provide training for the recruiting test that coaches need to take every year. Another viable solution is to create handouts consisting of the regulations they need to know, and provide those as the regulations change. Finally, a formal Power Point presentation regarding the NCAA rules and regulations about social media is another solution that could be taken into consideration.

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A BALANCED SCORECARD APPLICATION IN LOCAL ADMINISTRATIONS

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ABSTRACT

When measuring the performance of an institution business usually decide on a set of pre-established and generally accepted criteria. The success of performance measurement depends on the organization of the institutions and the suitability of the selected technique. The Balanced Scorecard is a performance management system that can be used in different sized organizations. Indicators that have a significant share in the performance of the institution but are difficult to measure should also be evaluated. The Balanced Scorecard transforms an organization's financial and non-financial objectives into logical performance measures. Four dimensions; Financial dimension, customer dimension, internal business process dimension and learning and development dimension. In this study, a performance evaluation study was conducted for the Urban Transportation Unit of a Metropolitan Municipality by using Balanced Scorecard method. The fuzzy AHP method was used to eliminate ambiguities in the application of the method and to clarify the cases that can not be expressed clearly.

1. Introduction

Performance management is an important aspect for achieving the targets set by local governments. The methods used in performance measurement and the results obtained from these methods become increasingly essential. It is important to use multidimensional performance measurement methods since local governments do not have core financial targets. In a rapidly developing world, goals must be accurately determined and measured performance must be managed to achieve the specified goals.

One of the multi-dimensional performance methods, the Corporate Performance Card method (Balanced Scorecard method), was first introduced to the literature by Kaplan and Norton with their published paper in 1992. This method is mainly based on the idea that performance measurement methods based on financial accounting measurements are now obsolete and lose their validity. The Corporate Performance Card is not only an advanced performance measurement system, but also a good management system. The system considers four dimensions that must be

balanced in measuring enterprise performance: financial, customer, internal processes, learning and growth. In this study, it was aimed to create a Corporate Performance Card for the Urban Transportation Unit of the Metropolitan Municipality of Erzurum and analyze the factors affecting the performance. Within the overall framework mentioned, the second part of the study indicates the work done by various authors with the Corporate Performance Card. In the third part of the study, information on performance management and Balanced Scorecard was given. In the same section, technical information of the fuzzy AHP method used to determine the factor weights of the performance card created in practice is also included. In the fourth part of the work, the work done for the Urban Transportation Unit of a Metropolitan Municipality for performance measurement was given. In this context, the creation of the Balanced Score Card is explained. In addition, fuzzy AHP was used in converting the linguistic variables determined into numerical results. In the fifth part of the study, the obtained results are briefly summarized and suggestions were given in the direction of scientific studies to be done in the future.

2. Literature Review

With the increasing demands and expectations of their stakeholders, government agencies now need to deliver more efficient and effective public services while overcoming the burden of reduced public budgets and resources(Sivarajah, Irani, & Weerakkody, 2015).

Local self government carries out diverse activities relating to the development of its managed area and ensuring local inhabitants quality of life. With limited financial, material and human resources is therefore necessary to carry out their activities looked foresight into the future and their activities implemented thoughtfully and with the expectation of a positive outcomes (Gecíková & Papcunová, 2014)

The decision-making process tends to be similar in all organizations, even if the decisions concern particular issues either in the public or private sectors. The effectiveness of decision models depends on the circumstances that shape the organization(Nogueira & Jorge, 2016). The reforms introduced in the management and accounting structures of public sector entities, in response to Public Management requirements, reinforce the role of accountability as a means to improve economy, efficiency and effectiveness in Public Administration. Accountability is no longer conceived as merely reporting about complying with norms and procedures, but as the need

to report on the allocation and use of public resources and the results attained, in order to allow assessing public officials' responsibilities(Nogueira & Jorge, 2016).

Here, contingency and institutional theories can be used to explain the reforms in public sector accounting, particularly to explore factors possibly affecting information usefulness in the decision-making process in the context of public sector entities, namely local authorities (Nogueira & Jorge, 2016). Kaplan and Norton (1992) developed the BSC as a new tool including operational measures, as well as financial ones, for performance evaluation. The BSC provides management with a set of measures that give a fast and comprehensive view of the business. The aspect of non-financial assets' accounting for 50-80% of a firm's value supports the importance of the BSC approach (Türüdüoğlu, Suner, & Yıldırım, 2014),(Kaplan & Norton, 2004)

Financial measurement alone does not reflect the organizational mission of governmental and non-profit organizations. Also the greatest difference between businesses and non-profit organizations is the achievement of the mission (Ekmekçi, 2014). Since the balanced scorecard doesn't require the measurement of financial terms, it could be easily applied by the public sector and non- profit organizations (Ekmekçi, 2014). The urban transportation system is generally based on the ISO LCA standards, requiring inclusion of all the life cycle stages mentioned in environmental product declarations [13]. The urban public transportation system, considered as a special industrial product, is composed by three components , namely infrastructure (road and bus station), fuel and vehicles (Meng, Liu, Yang, Hao, & Ulgiati, 2016).

BSC method is not just a grouping of important indicators of performance evaluation. Its consistent application provides a modern way of management, because it helps to align the businesses activities with the business processes of company´s value creation and the BSC to a method of strategic management which role is to align the interests of management with the interests of employees and the strategic goals with the operational management (Lesáková & Dubcová, 2016). As a strategic management tool, the BSC facilitates the translation of the organization's vision and strategic objectives into operational measures and critical drivers. The integration of both financial and nonfinancial performance measurement within the four perspectives contributes to a "balanced" approach in the monitoring of organizational performance (Zin, Sulaiman, Ramli, & Nawawi, 2013).

Staying competitive in the global economy needs to move forward new management practices in areas such as marketing, design, engineering, manufacturing, finance, accounting and human resources. The challenge is to implement new management tools so that available resources are thoroughly utilized in the production of quality products and services, which in turn enhance organizational competitiveness(Afonso & do Rosário Cabrita, 2015).

The BSC comprises four perspectives, namely finance, customer relations, internal business process and lastly, learning and growth. The financial perspective plays a dual role of defining the financial performance of an organization with the implementation and execution of the company's strategic plans, as well as evaluating the organization's profitability using tools such as the ROI (Return on Investment) and the EVA (Economic Value Added). The customer perspective is a leading indicator that helps the organization evaluates customer satisfaction with its brand or services. This is necessary to ensure strong customer loyalty, besides attracting new customers (Zin et al., 2013).

A wide range of research documenting the application of BSC in healthcare, education,

banking and retailing has been reported. The evolving applications of BSC and strategy map in the healthcare sector in Ontario, Canada, have been illustrated. A number of innovative approaches adopted by healthcare organizations and health systems in their implementation of Kaplan and Norton's strategy map and balanced scorecard are described. In 1995, Peel Memorial Hospital in Brampton, Ontario, BSC provided with a "framework for performance management and evaluation; the ability to translate the organization's strategic objectives into coherent performance measures; the alignment of seemingly disparate elements with organizational objectives and a focus on accountability at all levels (Farooq & Hussain, 2011).

3. Method

3.1.Balanced Scorecard

This approach has been used extensively in developing a strategic plan that incorporates more realistic goals and initiatives for achieving the outlined goals. The BSC enables managers to have a formalized mechanism that will achieve the balance between financial and nonfinancial results in the short and long term and is also a means to evaluate the performance of an organization through four traditional perspectives: financial, internal business process, customer and learning and growth . Following the identification process, the BSC is applied to these metrics with the

intention of evaluating clearly the performance of SC. Each of these perspectives should be translated into corresponding metrics and measures that reflect the strategic objectives. These perspectives should be periodically reviewed and updated as necessary and may even be extended in number. Measures included in the BSC should be monitored over time and integrated explicitly in the strategic processes of the SC. In order to make the BSC a successful approach, organizations should articulate goals for time, quality, performance and services and finally translate these objectives into specific performance measures. It makes no sense for organizations to have only financial measures, but rather a combination of these with operational measures (Afonso & do Rosário Cabrita, 2015).

Kaplan and Norton (1996) present the Balanced Scorecard as a model that provides executives with a comprehensive framework that can translate a company's vision and strategy into a coherent and linked set of performance measures. The model views the organizational performance from four perspectives: customer, financial, internal processes and learning and growth (Ivanov & Avasilcăi, 2014):

a. Customer perspective

Chuck Hannabarger, Frederick Buchman, Peter Economy agreed that all four Balanced Scorecard's perspectives have the same importance, but the customers are the main reason of existence for any organization. They think that employees from many organizations do not know what customers need and in which extent their activity affects them. The main concerns of the customers can be classified in four categories: time, quality, performance and service.

b. Internal business perspective

This perspective focuses on all activities and processes that are critical for the organization in providing the expected value for the customers. The main condition in obtaining the desired results from process improvements is to assess the organization performance, to identify the possible problems that affect the quality of the products.

c. Financial perspective

It is very important to know from where to get your money and how to invest them to become profitable. The financial indicators that are analyzed differ from company to company. The most common mistake that most of the organizations do is to focus too much on the financial indicators ignoring totally or partially the other perspectives.

d. Learning and growth perspective

Organizations must learn that employees are very important not only for their specific tasks, but also for their creativity and ability of developing new ideas. The need for employee knowledge, skills and abilities can be very important especially when new technologies and processes come to the market.

3.2.Fuzzy AHP Method

The analytic hierarchy process (AHP) is a multi-criteria decision-making tool developed by Saaty. AHP is a systematic procedure to represent elements of any problem in a hierarchical way. Since decision-making in the field of strategy formulation have a great deal of uncertainty associated, managers should be able to express some degree of confidence in their judgments. The hierarchy is structured from the top, usually the main objectives set by management, through the intermediate levels to the lowest level, usually the alternatives. These judgments are then translated into numbers. This method uses pair- wise comparison in the same hierarchy elements in each level using a scale indicating the importance of an element in relation to another. In the context of performance evaluation of SC, the AHP can be the best tool for prioritizing and selecting the best measure of performance in a given situation (Afonso & do Rosário Cabrita, 2015).

The Fuzzy AHP Method. AHP is one of the most extensively used MCDM analysis tools for modeling the unstructured problems in different areas such as politics, economic, social, and management sciences. AHP assumes that evaluation criteria can be completely expressed in a hierarchical structure. The data acquired from the decision makers are pairwise comparisons concerning the relative importance of each of the criteria, or the degree of preference of one factor to another with respect to each criterion. In the conventional AHP, the pairwise comparison is made by using a ratio scale. Even though the discrete scale has the advantages of simplicity and ease of use, it does not take into account the uncertainty associated with the mapping of one's perception (or judgment) to a number. In order to deal with the uncertainty and vagueness from the subjective perception and the experience of human in the decision-making process, many fuzzy AHP methods are proposed by various authors (Erkayman, Gundogar, & Yılmaz, 2012).

4. Illustrative Example

Financial dimensions criteria's

DIMENSIONS		GOALS
FINANCIAL DIMENSIONS	f1	Research and development studies need to be done
	f2	Increasing business capacity
	f3	Increasing Return on Investment
	f4	Increasing income
	f5	Increase resource efficiency
	f6	Increasing the budget realization rate and making efforts to ensure that the budget is realized
	f7	Shortening the return period of the investment
	f8	Use of income for the right investment purposes
	f9	Increase revenue per employee

Customer dimension criteria's

CUSTOMER DIMENSIONS		
	c1	Increasing service quality
	c2	Increasing customer loyalty
	c3	Increasing customer satisfaction
	c4	Reduction of customer complaints
	c5	Meeting or even exceeding customer expectations

Internal Processes Dimension Criteria's

INTERNAL PROCESSES DİMENSİON CRİTERİA	ip1	Providing fast, easy, transparent, economical, secure and all-around e-localgovernment applications
	ip2	Applying the digital document and archive system
	ip3	Increasing operational efficiency and productivity
	ip4	Reduce error and repeat rate in business processes

Learning and development dimension criteria's

LEARNING AND DEVELOPMENT DIMENSION CRITERIA		
	ld1	Improving and enhancing employee skills
	ld2	Assigning at least 15 staff members to outside seminars every year
	ld3	Determining and ensuring training needs of personnel by carrying out training needs analysis
	ld4	Increasing Employees' Participation to Management
	ld5	Increasing employee satisfaction

Refinement Process Outcome

FINANCIAL DIMENSIONS	9,0%
CUSTOMER DIMENSIONS	50,7%
INTERNAL PROCESS DIMENSION	11,2%
LEARNING AND DEVELOPMENT DIMENSION	29,1%

5. Conclusion

As a result of the meticulous work carried out in the public transport branch, it was decided that the Corporate Performance Card method could be most suitable, and this meticulous work continued in the design process. Working with a group of experts who have fully mastered the process within the organization has increased the accuracy of the information obtained as a result of the study. One of the important points to reach success in establishing the corporate performance card is created for the institution and none of the important points are missed. The application of a specific method from the literature directly to the firm causes misconception in the study because the focus of each firm is vital and accordingly their purpose will be different. The work is based on this awareness and is specifically designed for the corporate performance card for

The vision and mission statements as well as strategies have been clarified before the dimensions of the corporate performance card are determined. The dimensions to be worked on after this phase are determined as: finance dimension, customer dimension, internal processes and learning development dimension. Critical success factors have been identified for each of these dimensions. Performance criteria were established in order the institution to measure them in line with the objectives set for these success factors and to see the activities of the work done. After

the objectives prepared for each dimension, these goals were to determine the contribution to the main dimension performance and to set the priority order.

In doing this study, the literature search was meticulously conducted and it was decided that it was most appropriate to translate the linguistic expressions given by the experts into a mathematical system by translating them into meaningful numbers. The most suitable method for this purpose is the fuzzy AHP because the appropriate method for weighting each of the linguistic expressions is the fuzzy AHP. In this method, it is advantageous to use it in more uncertain situations where definite expressions can not be determined and to evaluate the criteria by means of a binary comparison method.

As a result of the study, the order of importance of the four dimensions determined. Customer dimension is the most important dimension with 50.7%, followed by learning and gaining dimension (29.1%), internal process dimension is 11.2% and financial dimension has 9% designation. Once the weights of the objectives set in the customer dimension have been identified, the order of priority for these objectives has also been determined. The first two of the objectives that impact success are: meeting or even anticipating customer expectations (34.2%) and increasing service quality (30.8%). On the level of learning and development, the increase in employee satisfaction (54,3%) and the development of employee talents (22,4%) took priority. The dimensions of finance and internal processes with close percentages in terms of major dimensions are also measured in terms of sub-objectives.

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PARAMETRIC INFLUENCE AND OPTIMIZATION OF WIRE-EDM ON HOT DIE STEEL

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ABSTRACT

Wire-cut Electro Discharge Machining (WEDM) is a special form of conventional EDM process in which electrode is a continuously moving conductive wire. The present study aims at determining parametric influence and optimum process parameters of Wire-EDM using Taguchi's technique and Genetic algorithm. The variation of the performance parameters with machining parameters was mathematically modeled by Regression analysis method. The objective functions are defined as Dimensional Error (DE), Surface Roughness (SR) and Volumetric Material Removal Rate (VMRR). Experiments were designed as per Taguchi's L_{16} Orthogonal Array (OA) where in Pulse-on duration, Current, Pulse-off duration, Bed-speed and Flushing rate have been considered as the important input parameters. The matrix experiments were conducted for the material Hot Die Steel (HDS) having the thickness of 40 mm. The Heat Affected Zone (HAZ) characteristics of the eroded materials was assessed by Scanning Electron Microscope (SEM) and the microhardness of the material was tested using Vickers microhardness tester. The results of the study reveal that among the machining parameters, it is preferable to go in for smaller pulse-off duration for achieving over all good performance. Regarding pulse-on duration, higher values are recommended for error constrained machining with higher MRR and constrained/limited values for attaining good surface texture. Smaller current is suggested for better surface finish/texture control, medium range for error control and high value for MRR. Finally, the validation exercise performed with the optimum levels of the process parameters. The results confirm the efficiency of the approach employed for optimization of process parameters in this study.

Key words: Genetic Algorithm, Regression, Taguchi Analysis, Wire Cut Electro Discharge Machining (WEDM).

1. Introduction

The mechanism of material removal in a conventional EDM process has been well documented. By choosing the electrode as a continuously moving conductive wire, the capability of the machining can be augmented.

A wire cut EDM can machine exotic material and complex shapes. Higher productivity, desired accuracy and better surface finish are the stay features of WEDM. Researchers have conducted studies on the performance of WEDM and concluded that even a skilled labourer finds it difficult to obtain optimal performance due to operational constraints. An effective way to tide over this problem is to determine appropriate relationship between the performance indicators of the process and its controllable input parameters such as pulse-on duration, current, pulse-off duration, bed-speed and flushing rate. In this present study of WEDM, the effect of controllable input parameters on HDS are investigated.

Since Wire-cut EDM is an essential operation in several manufacturing processes, several research work have been carried out to improve the machining performance of WEDM; namely surface finish, accuracy and material removal rate. Because of its complex and stochastic nature and the increased number of variables involved in the operation, the full potential utilization of this process is not completely solved. Number of authors has performed their research related to optimal parameter setting in this process.

Lin, et al, [1] presented the use of grey relational analysis based on an orthogonal array and the fuzzy-based Taguchi method for the optimization of EDM process with multiple process responses. Both approaches can greatly improve process responses such as the electrode wear ratio, material removal rate and surface roughness. However, it seems that the method based on the orthogonal array with the grey relational analysis method is more straightforward than the fuzzy-based Taguchi method for optimizing the EDM process with the multiple process responses.

Kiyak and Akır [2] have carried out a study on influence of EDM parameters on surface roughness for machining the tool steel (AISI P20) which is widely used in the production of mold and die. It was observed that surface roughness of workpiece and electrode were influenced by pulse current and pulse-off duration. Higher values of these parameters increased surface roughness. Lower current, pulse off duration and relatively higher Pulse-off time produced a better surface finish.

S. S. Mahapatra & Amar Patnaik [3] identified the relationship between the control factors and responses by means of nonlinear regression analysis, resulting in a valid mathematical model. Genetic Algorithm is employed to optimize the WEDM process with multiple objectives. The study demonstrates that the WEDM process parameters can be adjusted using these techniques to achieve better metal removal rate, surface finish and cutting width simultaneously.

K.H. Ho et al [4] investigated the interrelationship between the various factors affecting the process and identifying the optimal machining condition from the infinite number of combinations. Several monitoring and control algorithms based on the explicit mathematical models, expert's knowledge or intelligent systems have been reported to reduce the inaccuracy caused by the vibration behavior and static deflection of the wire.

2. Experimental Details

The experimental studies were performed on a CONCORD DK7720C WEDM machine. Different settings of five controllable factors such as pulse-on duration, current, Bed speed, pulse-off duration, and flush rate were used in the experiments, while wire tension and Servo voltage were kept constant throughout the experiment. The value of wire tension is fixed to 1500gf and value of servo voltage is fixed to 100V.

Molybdenum wire with 0.18 mm diameter was used as wire electrode in the experiments. A block of square cross section having dimensions 10 mm × 10 mm was cut on a workpiece. The thickness/height of the work piece was 40 mm (eroding section 10 × 40 mm^2) and the angle of cut was vertical. The gap between wire and work piece was 0.02 mm and was (constantly) maintained by a computer controlled positioning system. After considering the machining conditions, control factors and their four levels were chosen as shown in Table 1.

Table 1 Control factors and their levels

Control Factors	Level				
	I	II	III	IV	Unit
Pulse-on (Pon)	16	20	24	28	µs
Current (C)	3	4	5	6	A
Bed speed (BS)	15	20	25	30	µm/s
Pulse-off (Poff)	5	7	9	11	µs
Flush Rate(FR)	1.2	2.4	3.6	4.8	Lit/min

The dimensional accuracy was measured using a digital micrometer having least count 0.001mm (1 micron). By measuring the dimensions of the machined part at three different positions along the length of the work piece, the error was calculated. The maximum deviation is considered as the response variable. To evaluate the volumetric material removal rate, (mm^3/sec) the machined volume was calculated and divided by the elapsed machining time.

Volumetric Material Removal Rate = $(0.09 + 0.02) \times 2 \times 40 \times (10 \times 4 + 1.5)$ / Time taken

Diameter of the Molybdenum wire = 0.18 mm.

Spark gap = 0.02 mm.

Wire entry & exit length = 1.5 mm.

The average surface roughness value Ra (µm) was obtained by measuring the mean absolute deviation from the average surface level using a Handysurf E-35A portable surface measuring unit. Among various parameters available in the surface measuring instrument, the parameter Ra was considered in the present study. Surface roughness along the length and across the length was measured. Generally surface roughness is measured parallel to movement of the wire. In the present study, roughness was measured along both parallel and perpendicular to the direction of the wire movement in machining. The maximum dimensional deviation and surface roughness are considered for the analysis. The traverse length considered for the measurement of surface roughness was 12.5 mm along the length and 6 mm across the width of the work sample. The dimensional error is checked on points along Y1Y2 direction and the surface roughness is measured along X1X2 direction over a sampling length of 6 mm as shown in Figure 1.

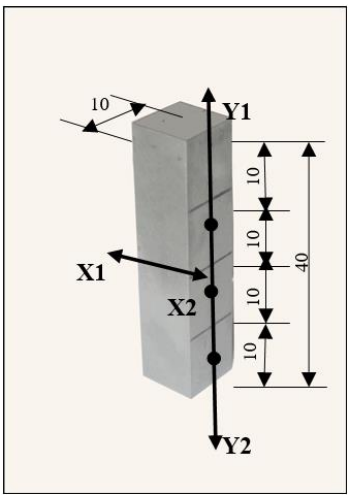


Figure 1 Measuring directions

For microstructure analysis, JOEL 6510LV Scanning Electron Microscope (SEM) was used.

3. Multi-Objective Optimization Problem (MOOP) & Genetic Algorithm (GA)

As the name suggests, a Multi-Objective Optimization Problem (MOOP) deals with more than one objective function. A multi-objective optimization problem has a number of objective functions which are to be minimized or maximized. There are several multi-objective optimization techniques used for this purpose. It was decided to select Genetic Algorithm (GA) for the present work. They operate on a randomly generated population in the search space simultaneously and perform a global optimization by the three genetic operations, ie., selection, cross over and mutation. According to evolutionary theory, only the fittest suited elements of a population can survive and generate offsprings, there by transmitting their biological heredity to new generations. The evolution starts from an initial population of completely random individuals represented in binary strings of 0's and 1's and are involved in the generation process. In the present study, the target is to minimize the Dimensional Error and Surface Roughness and maximize the material removal rate. Accordingly, the objective function for the optimization problem considered here is defined as f (objective) = DE+SR-MRR [5].

4. Results and Discussions

The data pertaining to parametric influence on dimensional deviation, surface roughness and material removal rate are presented in the Table 2.

Table 2 Parametric influence on DE, SR and MRR

Run	Pulse-on duration (µs)	Current (A)	Bed Speed (µm/s)	Pulse-off duration (µs)	Flush rate (lit/min)	Dimensional Error (µm)	Surface Roughness Ra (µm)	MRR (mm^3/ min)
1	16	3	15	5	1.2	2	2.08	3.338
2	16	4	20	7	2.4	10	2.27	3.926
3	16	5	25	9	3.6	22	2.35	4.8
4	16	6	30	11	4.8	24	2.48	6.08
5	20	3	20	9	4.8	28	2.36	3.338
6	20	4	15	11	3.6	30	2.44	3.204
7	20	5	30	5	2.4	3	2.43	7.023
8	20	6	25	7	1.2	8	2.5	6.407
9	24	3	25	11	2.4	16	2.49	4.76
10	24	4	30	9	1.2	10	2.6	5.002
11	24	5	15	7	4.8	6	2.7	3.4
12	24	6	20	5	3.6	4	2.7	6.086
13	28	3	30	7	3.6	10	2.85	7.4
14	28	4	25	5	4.8	6	2.47	6.389
15	28	5	20	11	1.2	16	3.06	5.186
16	28	6	15	9	2.4	12	3.02	4.337

The values indicated are the average of 3 readings (trials). With lower levels of machining parameters, the experimental value shows the least deviation.

4.1 Parametric Influence on Dimensional Error (DE)

Response plots on dimensional deviation are shown in Figure 2. Higher Signal to Noise (S/N) ratios are for minimizing the target (dimensional deviation) ie, minimum deviation in dimension can be obtained with higher S/N ratios.

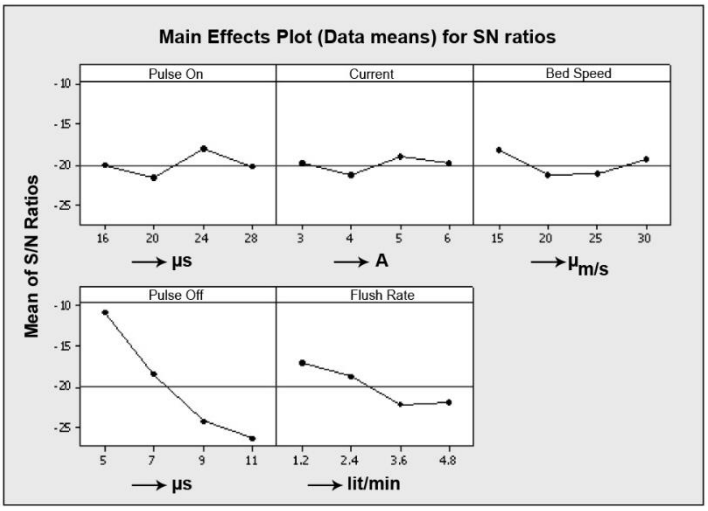


Figure 2 Response plot on Dimensional Error

Among the machining parameters, Pulse-off duration and Flush rate influence most on dimensional deviation. With smaller Pulse-off duration and Flush rate, greater control on dimensional deviation can be obtained. Also with smaller Bed Speed, an improvement in dimensional deviation control can be obtained. Regarding Pulse-on duration and Current, medium range exerts better control.

4.2 Micrographic Observation

Basic microstructure of HDS (before machining) and the cross section of spark eroded HDS material with conditions leading to higher dimensional error (30 μm) is shown in Figure 3 and 4 respectively. The basic microstructure clearly shows finely dispersed carbides with Ferrite boundary ensuring medium hardness.

fine & uniform distribution of carbides

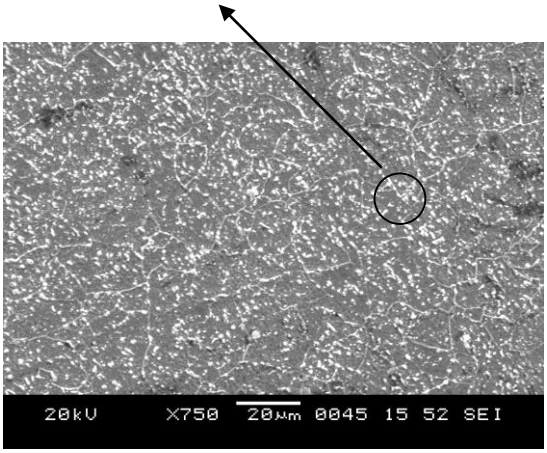
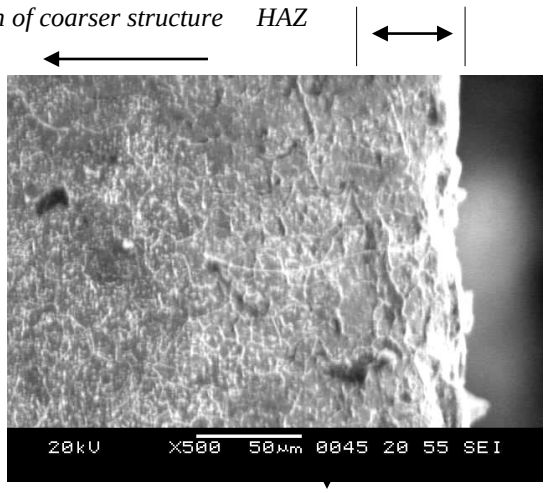


Figure 3 Microstructure of HDS (before machining)

gradation of coarser structure *HAZ*



resolidified layer

Figure 4 Typical HAZ – Micro structure of sample-6 (conditions leading to higher dimensional error)

Figure 4 shows relatively thicker (20 µm) white layer of resolidified material. The resolidified layer is relatively non-uniform containing solidified loops - Also relatively coarser structure below the resolidified material can be seen, accounting for the heat affected, coarsening of the material. This results in reduction of hardness/strength of the material in the surfacial region (below the white layer). Typical micro hardness variation over the cross section of the eroded specimen machined with conditions leading to higher dimensional deviation is shown in Figure 5.

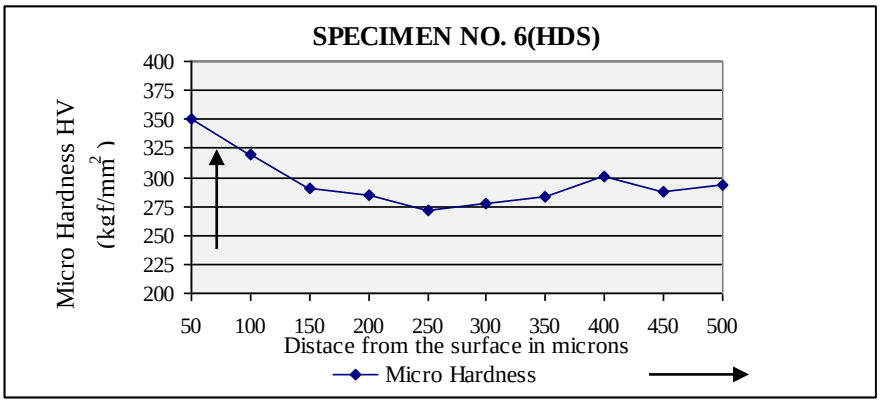


Figure 5 Variation in Microhardness

The surface has been spark hardened with the substrate experiencing a reduction in hardness possibly due to coarsening of the material and over heating. This gradient in hardness

affect the performance of this material. Medium pulse-on duration, current and high pulse-off duration result in such a variation.

4.3 Parametric Influence on Surface Roughness

Typical monitored response plots on surface roughness are shown in Figure 6.

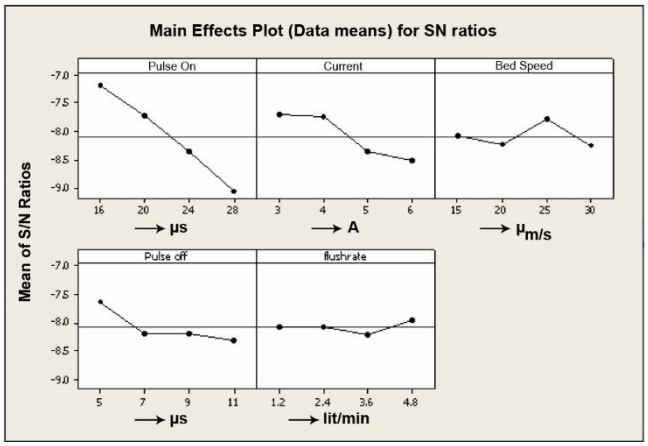


Figure 6 Response Plot on Surface Roughness

It is seen that pulse-on duration and current exert visible influence on surface texture, followed by pulse-off duration. Bed speed and flush rate are seen to influence only marginally. Comparing the optimized parameters for controlled dimensional deviation and surface texture, distinct difference in the value of pulse-on duration, bed speed and flush rate can be seen. While higher pulse-on duration is recommended for error control, minimum pulse-on duration is for surface control, smaller current value for texture control, larger bed speed and flush rate for texture control. Thus it can be inferred that unlike the dimensional tolerance control/error toleranced machining, for attaining good surface texture preference is for smaller pulse-on duration, smaller current, smaller pulse-off duration and higher flush rate.

4.4 Parametric Influence on MRR

The response plots indicating the parametric significance with regards to MRR are shown in Figure 7.

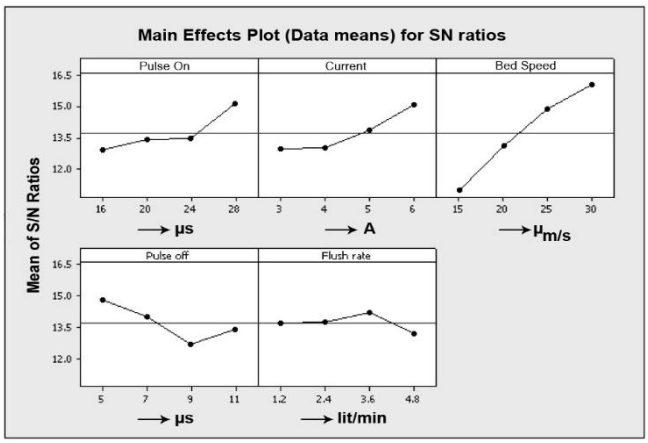


Figure 7 Response Plot on MRR

The parameters that influence material removal rate are pulse-on duration, current, bed speed and flush rate. Flush rate exerts a moderate influence on material removal rate while bed speed has a direct influence in a positive manner. Pulse-off duration has a negative influence.The optimized parameters on DE, SR and MRR are illustrated in Table 3.

Table 3 Optimized parameters on DE, SR and MRR

Sl No.	Control Factors	Optimum level on DE	Optimum level on SR	Optimum level on MRR	Unit
1	Pulse-on	24	16	28	µs
2	Current	5	3	6	A
3	Bed Speed	15	25	30	µ/s
4	Pulse-off	5	5	5	µs
5	Flush rate	1.2	4.8	3.6	ltrs/min

The values are typical for rough machining conditions facilitating higher MRR. It is seen that upper bound values of MRR tend to progressing rise with high pulse-on combination, which lower bound values tend to increase marginally. Comparing the optimized values for dimensional deviation, surface roughness and material removal rate, it is seen that for control of dimensional deviation and higher MRR, relatively higher pulse-on duration is recommended, while for surface finish medium pulse-on duration is recommended. Also higher current is recommended for dimensional deviation control and higher MRR. All criteria call for least pulse-off duration. Higher Flush rate is recommended for surface finish; it can be inferred that higher beam intensity is for

MRR and error control while medium intensity and higher flush rate (facilitating debris/shorting free electrode gap) for finish control.

4.5 Regression Model

The statistical analysis of data pertaining to parametric influence on dimensional deviation, surface roughness and material removal rate results in equation 1, 2 and 3 respectively. The regression coefficient (R squared = 1 - (Residual Sum of Squares) / (Corrected Sum of Squares)) for the above said equations are 0.889, 0.882 and 0.880 respectively.

$$DE = 7.976 \times P\text{-}on^{-0.750} \times C^{-0.436} \times BS^{-0.352} \times P\text{-}off^{1.930} \times FR^{0.394} - \quad (1)$$

$$SR = 0.498 \times P\text{-}on^{0.394} \times C^{0.150} \times BS^{0.1200} \times P\text{-}off^{0.098} \times FR^{-0.004} - \quad (2)$$

$$MRR = 0.086 \times P\text{-}on^{0.442} \times C^{0.345} \times BS^{0.853} \times P\text{-}off^{-0.235} \times FR^{0.027} - \quad (3)$$

Regression analysis on dimensional deviation (equation 1) shows that Pulse-off duration and Flush rate exert positive/direct influence on dimensional deviation, while Pulse-on duration, current and Bed Speed exert an inverse influence. From the regression analysis on S/R (equation 2), it is seen that all the parameters barring flush rate exert a direct/positive influence on surface roughness.

4.6 Multi-Objective Optimization Using Genetic Algorithm (GA)

The dependant parameters/performance evaluation parameters are Dimensional Error (DE), Surface Roughness (SR) and Material Removal Rate (MRR) which are the functions of independent parameters Pulse-on duration (Pon), Current (C), Pulse-off duration (Poff), Bed-speed (BS) and Flushing Rate (FR). So a function has been generated in relation between the various dependant and independent parameters of the following form.ie.,

DE = F1 (Pon, C, Poff, BS, FR),

SR = F2 (Pon, C, Poff, BS, FR) and

MRR = F3 (Pon, C, Poff, BS, FR).

This functional relation is obtained by performing multiple linear regression analysis. In this problem, the target is to minimize the dimensional deviation, surface roughness and maximize the material removal rate. Thus the problem formulation becomes a multi-objective optimization

considering the above three objective functions [6]. The multi-objective optimization is done using genetic algorithm in which the objective function is defined as a composite functions of the above three, defined as obj = DE+SR-MRR. The objective function is minimized by executing the GA. The convergence history or fitness characteristics of the GA is illustrated in Figure 8. It is clear from the figure that no substantial change in the fitness value is observed after 40 generations. This indicates that, the parameters have reached the optimum values ensuring minimum dimensional error, surface roughness and maximum material removal rate. The values are shown in Table 8. In executing the GA, the following values of input parameters are used [7].

Population size = 100

Number of variables = 5

Probability of crossover = 75%

Probability of mutation = 5%.

The lower and upper bound/level of these process variables used in the optimization procedure are respectively given by

LB = [16 3 15 5 1.2]

UB = [28 6 30 11 4.8]

The convergence history of the fitness value is regularly monitored as the generation proceeds and the algorithm is terminated when the fitness value reaches at threshold consistent value for a certain number of generations. However the optimized parameter values can change if any of the desired performance indicators (DE, SR or MRR) is given weightage. The optimized parameters for the function with equal and more weighting for the responses are shown in Table 4.

Table 4 Optimized values and attainable values

Sl No.	Dependant parameters	Equal weighting	weighting for DE	weighting for SR	weighting for MRR
1	Pulse-on duration	27.995974	27.997039	16.25252	28.002
2	Current	5.999558	5.997720	3.099925	6.0070
3	Bed speed	29.992016	29.987529	15.25652	30.003633
4	Pulse-off duration	5.012633	5.002980	5.652555	5.002408
5	Flush rate	4.754172	1.201789	1.205286	4.800906
Attainable Values		DE =3.76 SR = 4.23 MRR=9.04	DE = 2.17 SR = 4.26 MRR= 8.71	DE =5.71 SR = 2.83 MRR= 4.96	DE =3.76 SR = 4.23 MRR= 9.84
Experimental Values		DE =3.06 SR = 3.13 MRR=9.84	DE = 2.05 SR = 4.28 MRR= 7.92	DE = 5.20 SR = 2.63 MRR = 4.66	DE =3.25 SR = 4.15 MRR= 9.95

For a given weighting on DE, the objective function is changed as obj = DE×10+SR-MRR. The corresponding fitness characteristics is shown in Figure 9. A reduction is observed only in flush rate level. When the weighting is given for SR the objective function gets modified as obj = DE+SR×10-MRR. Pulse-off duration remains steady with its lower value and all other parameters are showing a downward trend. Further, with weighting on MRR, and the modified objective function obj = DE+SR-MRR×10. There is no appreciable change in parameter levels.

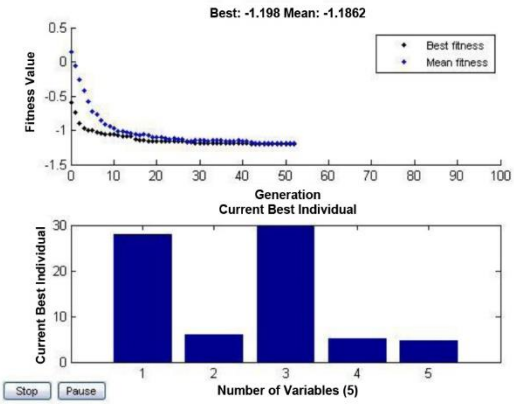


Figure 8 Equal Weighting (3 responses)

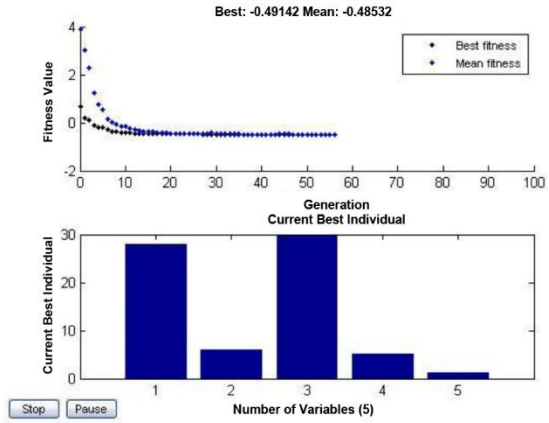


Figure 9 Weighting for DE

The confirmation run was conducted taking into account the multi-objective optimized parameters for the HDS material. It was found that the machining performance was improved and the experimental values are correlating well with the theoretical values/attainable values as shown in Table 4.

With equal weighting for end parameters, the dimensional error estimated using the genetic algorithm is 3.76 μm while the experimental value is 3.06 μm. The estimated value of surface roughness is 4.23 μm while the experiments gave the result of 3.13 μm. The actual material removal rate was 9.84 mm^3/min while the calculated value gave only 9.04 mm^3/min. All the three parameters indicate marginal difference between theoretical prediction and experimental results.

In the next step, weighting was given for dimensional error by modifying the algorithm and was subjected to close scrutiny. Here, the estimated and experimental values of accuracy were 2.17 μm and 2.05 μm respectively. The surface roughness was 4.26 μm and 4.28 μm respectively indicating very close relation between end results. However, the volumetric removal rate fell drastically from 8.71 mm^3/min to 7.92 mm^3/min indicating a clear loss in MRR.

Further, weighting in the algorithm was given to surface roughness. The accuracy was changed from 5.71 μm to 5.2 μm between theoretical and experimental values. The surface

roughness was very proximate and varied to 2.63 μm from 2.83 μm. There was a positive decline in the material removal rate from 4.96 mm^3/min to 4.66 mm^3/min.

Finally, the algorithm was modified giving weighting to material removal rate. As was done in the previous cases, the theoretical values were computed using the algorithm and verified with the laboratory results for its consistency. The accuracy were 3.76 μm and 3.25 μm respectively. The surface roughness was 4.23 μm and 4.15 μm and material removal rate changed from 9.84 mm^3/min to 9.95 mm^3/min.

While confirming the validity of the Genetic Algorithm, the tabulated statement reveals the following.

1. The algorithm developed can be used as a flexible tool for controlling the end parameters.
2. The algorithm can be used to provide priority for parameters by suitably changing the index, there by the weightage.
3. Higher surface finish can be obtained only at the expense of the material removal rate.
4. The MRR can be augmented only by sacrificing the dimensional accuracy/surface finish.

5. Conclusions

The following are the important conclusions drawn from the present work.

- It is preferable to adopt larger spark intensity in terms of higher pulse-on duration, low pulse-off duration, high current, low flush rate and bed-speed for reducing dimensional deviation in the erosion of HDS material.
- Low pulse-on duration (16 μs) low current (3A), low pulse-off duration (5 μs), low bed-speed (15 μm/s) and low flushing rate are the optimized parameters for good surface texture production.
- High MRR can be attained by adopting high spark intensity parameters, high bed-speed and medium flush rate.

- Multi – objective hybrid optimization has shown that with pulse-on = 28 µs, Current = 6A, Bed-speed = 30 µm/s, Pulse-off = 5 µs and flush rate of 4.8 lit/min are the optimized values for good erosion of HDS material.
- HDS machined with low level of erosion parameters has shown a HAZ containing thin white layer of re-solidified material and thermally softened substrate material.
- The thickness of the white layer in HAZ, spark hardening and coarsening of the substrate are directly related to spark intensity.
- Minimum pulse-off duration is ideal for better dimensional accuracy, surface finish and high material removal rate**.**

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FACILITY LAYOUT OPTIMIZATION USING FUZZY WEIGHTED QUADRATIC ASSIGNMENT PROBLEM (FQAP): A CASE STUDY UNDER A COMPANY

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ABSTRACT

Facility layout directly affects the material handling costs of a company. Material handling costs are a major part of the total production cost. The most important objective of the facility layout problems is to minimize the material handling cost. The material handling cost is stated as multiplication of the distance, the volume of handled products and the unit cost of the material handling between the facilities or departments. Because it is difficult to change the volume of the production, most facility designers focus on reducing the distance between the facilities or departments. In this paper, two different facility layout altenatives are implemented for a company which produces tubes. The total facility layout area of the company is divided into equal areas and assigned to the existing departments by solving the classic Quadratic Assignment Problem (QAP) formulation in GAMS mathematical programming language. Additionally, activity relationship schedule between departments are expressed as fuzzy numbers and used in objective function of QAP. The results obtained have shown that fuzzy weighted Quadratic Assignment Problem (FQAP) solution have been better classic QAP.

Keywords: Facility layout, QAP, Fuzzy weighted QAP, Fuzzy logic

1. Introduction

Facility layout design problems are commonly studied by the non-polynomial hard (NP-hard) optimization problems. Facility layout design means planning for the location of all workstations, machines, service areas, material and other storages, restrooms, lunchrooms, drinking fountains, offices, etc. within the buildings [1]. The facility layout problem determines the physical organization of a manufacturing or service system, which is the most widely-studied combinatorial optimization problem. It is concerned with finding the most efficient arrangement of m indivisible departments with unequal area requirements within a facility [2].

The facility layout design is a key to improving the productivity of a production system [3]. Its objective is to minimize the total cost relationships among the departments, machines and facilities [4]. Additionally, an efficient facility layout can reduce the manufacturing lead time [3].

Conventionally, the effectiveness of layout problems has been attributed to the flow of materials. The material handling cost is

commonly used to evaluate alternative layout designs. The location of facilities in a production system is determined under the criterion of material handling cost minimization [5]. The objective function for minimizing the total material handling cost is given by [6]:

$$\sum_{i=1}^{n} \sum_{j=1, i \neq j}^{n} d_{ij} . f_{ij} . c_{ij}$$

n= the number of departments;

fij= the total flow between department i and j, where i,j= 1,2,…,n;

dij= the distance between department i and j, where i,j= 1,2,…,n;

cij= the cost for moving per unit material from department i to department j, where i,j= 1,2,…,n.

The arrangement of the facilities in the service area is referred to a "facility layout problem" in general. Facility layout is known to have an important effect on manufacturing costs, productivity, etc. A well-designed placement of the facilities contributes to the effectiveness of processes and can reduce the total operating expenditures up to 50% [1].

The facility layout problem (FLP) is the most studied combinatorial optimization problem in a facility layout design [7]. The various methods and approaches are used for solving FLPs in the literature. Some of these use several heuristics such as the genetic algorithm [8,9,10,11,12,13,14,15,16,17,3,18,19] simulated annealing [5,20,21,22], the hybrid heuristics [23], the ant colony algorithm [24,25,4,26,1,27,23,19], the Quadratic Assignment Problem [28,29,30,31,27,32,19,33], the simulation-based techniques [34,35,36].

In this study, we have assumed that the total facility layout area of the company is divided into equal areas and assigned to the existing departments of these equal areas by solving the QAP and FQAP in GAMS mathematical programming language.

2. Industry Application

2.1. Improving the Layout Alternatives Using the Classic QAP and Fuzzy Weighted QAP

The facility layout design problem is a largely studied non-polynomial hard (NP-Hard) combinatorial optimization problem [1]. QAP was introduced by Koopmans and Beckman in 1957 and a NP-Hard problem [25]. The QAP is a significant combinatorial optimization problem in

theory and practice. Many problems (backboard wiring, campus and hospital layout, etc.) can be formulated as QAPs. The QAP can be defined as the problem of assigning a group of pieces to a group of facilities or departments with given distances between the facilities or departments and flows between the pieces. The goal is to place the pieces on facilities in such a way that the total material handling cost is minimal [32].

The Quadratic Assignment Problem is a variety of assigning problem often seen in facility location and layout studies. The basic difference of the Quadratic Assignment Problem from the classic assignment problem is that in the Quadratic Assignment Problem there is interaction between assigning pairs, leading to a non-linear objective function. Facility layout problems are problems that needed the assessment of various flow relationships and in the literature the Quadratic Assignment Problem is frequently used for solving these problems. The Quadratic Assignment Problem is one of the most difficult problems in the NP-hard class, which implies that finding a polynomial time algorithm to solve it is unlikely [28]. Indeed, the computational complexity of QAP is such that even instances of size 20≤ n ≤30 represent a real challenge for the current exact approaches [38].

The QAP initial formulation is due to Koopmans and Beckman, where the cost of assigning facility i to j and of facility k to location l is fik.djl with fik denoting the material flow per unit time between facilities i and k and djl denoting the distance between locations j and l. Define xij to be 1 if facility i is assigned to location j, and 0 otherwise [39]. The formulation of the QAP is as follows:

$$\text{Minimize} = \sum_{i,j,k,l=1}^{n} f_{ik}.d_{jl}.x_{ij}.x_{kl}$$

$$\sum_{i=1}^{n} x_{ij} = 1, \quad \forall j \in \{1,...,n\}$$

$$\sum_{j=1}^{n} x_{ij} = 1, \quad \forall i \in \{1,...,n\}$$

$$x_{ij} \in \{0,1\}$$

The application of this study is to assign existing departments to equal areas by solving the above QAP formulation in GAMS mathematical programming language if the total facility layout area of the company is divided into equal areas.

The inputs and the assumptions of the problem are as follows:

The production area to be designed for the company includes seven departments. These are raw material storage, press department, weld department, supplier manufacturing department, mechanical test department, finish department and storage.

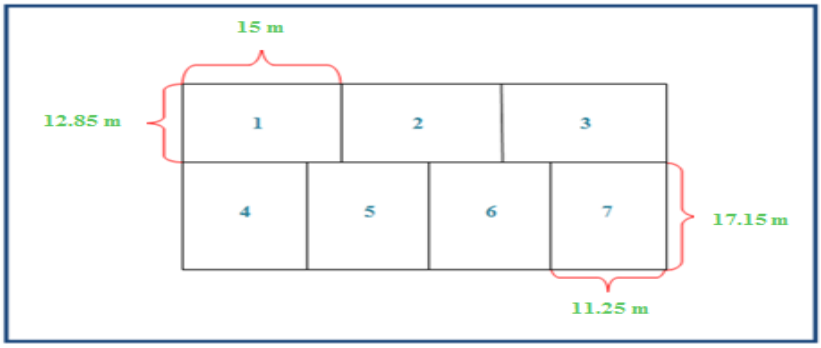
The from-to chart which shows the volume of handled products between the departments is given by Table 1. This chart has been created for monthly average production capacity of the company. Furthermore, each value of this chart has been implied as strongbox number which is executed back and forth between the departments because materials are handled by strongboxes.

Table 1. The from-to chart

Departments	**Departments**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	0	200	0	0	0	0	0
2	0	0	300	67	0	0	0
3	0	0	0	0	0	2500	0
4	0	0	100	0	0	0	0
5	0	0	0	0	0	2500	0
6	0	0	0	0	2500	0	2500
7	0	0	40	0	0	75	0

The total facility layout area of the company is divided into equal areas. According to this, the total area (1350 m2) assigned to the departments have seven equal areas, each one about 192.8 m2. For each department, the area needed is no more than 198.2 m2 (Fig.1).

Figure 1. The total facility area



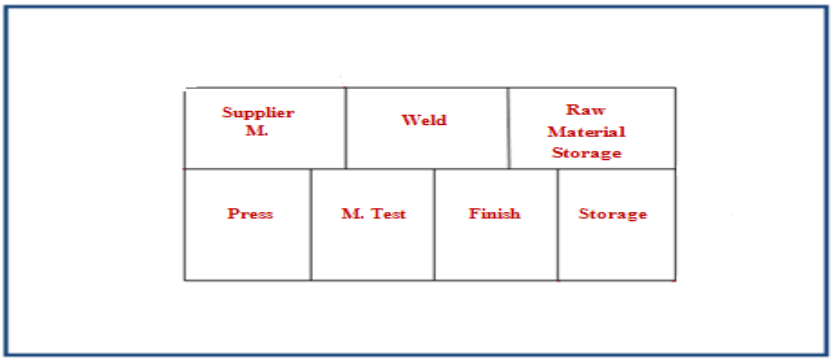
- The distances between these areas are rectilinear distances between the centres of gravity of these areas (Table 2).

Table 2. The rectilinear distances between the locations (meter)

Areas	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	-	15	30	16.875	28.125	39.375	50.625
2	15	-	15	31.875	32.675	32.675	31.875
3	30	15	-	46.875	37.5	20.625	16.875
4	16.875	31.875	46.875	-	15	22.5	30
5	28.125	32.675	37.5	15	-	15	22.5
6	39.375	32.675	20.625	22.5	15	-	15
7	50.625	31.875	16.875	30	22.5	15	-

The number of facilities of this layout problem we have discussed is fewer. Because of that, the solution is reached by the QAP model in a matter of seconds. Under the specified constraints, at the end of 21 iterations, the optimum value of the objective function has been found to be 1631057,5. According to the solution, variables Xij that takes value 1 are: X13, X24, X32, X41, X55, X66, X77 . Therefore, the assignments are as follows; raw material storage to location number 3, press department to location number 4, weld department to location number 2, supplier manufacturing to location number 1, mechanical test to location number 5, finish department to location number 6 and storage to location number 7 (Fig.2).

Figure 2. The new layout by solving the QAP model



Fuzzy set theory was proposed by Zadeh in 1965. A fuzzy set is a set with a straight limit which permits a partial membership. Consequently, the concept of a membership is a degree which reflected as a number between 0 and 1, We have accepted triangular fuzzy numbers for qualitative expressions used in an activity relationship schedule. As shown in the Table 3, in this study, qualitative expressions used in activity relationship schedule between departments are transformed into triangular fuzzy numbers as =(l,m,u). These fuzzy numbers are clarified using the formula in equation (1) and added as a multiplier (wik, fuzzy relation weight between department i and department k) to the objective function of classic QAP. Constraints for fuzzy weighted QAP are as classic QAP model.

$$P(\ ) = M = (l+4m+u)/6 \qquad (1)$$

Table 3. The triangular fuzzy numbers corresponding to qualitative expressions

Qualitative expression	**Triangular fuzzy number**
Absolutely necessary (A)	(8,9,9)
Especially important (E)	(6,7,8)
İmportant (I)	(4,5,6)
Ordinary closeness (O)	(2,3,4)
Unimportant (U)	(1,1,1)

In Table 4, 5 and 6 respectively activity relationship schedule between departments, activity relationship schedule which is expressed as triangular fuzzy numbers and activity relationship schedule which is clarified are shown.

Table 4. Activity relationship schedule between departments

Departments	**Departments**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	U	O	U	U	U	U	U
2	O	U	O	U	U	U	U
3	U	O	U	O	U	E	O
4	U	U	O	U	U	U	U
5	U	U	U	U	U	A	U
6	U	U	E	U	A	U	E
7	U	U	O	U	U	E	U

Table 5. Activity relationship schedule with triangular fuzzy numbers

Departments	**Departments**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
2	(2,3,4)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
3	(1,1,1)	(2,3,4)	(1,1,1)	(2,3,4)	(1,1,1)	(6,7,8)	(2,3,4)
4	(1,1,1)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
5	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(8,9,9)	(1,1,1)
6	(1,1,1)	(1,1,1)	(6,7,8)	(1,1,1)	(8,9,9)	(1,1,1)	(6,7,8)
7	(1,1,1)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(6,7,8)	(1,1,1)

Table 6. Activity relationship schedule which is clarified (wik)

Departments	**Departments**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	3	1	1	1	1	1
2	3	1	3	1	1	1	1
3	1	3	1	3	1	7	3
4	1	1	3	1	1	1	1
5	1	1	1	1	1	9	1
6	1	1	7	1	9	1	7
7	1	1	3	1	1	7	1

As in classic QAP, fuzzy weighted QAP has been solved in GAMS. Under the specified constraints, at the end of 21 iterations, the optimum value of the objective function has been found to be 1240371,250. According to the solution, variables Xij that takes value 1 are: X17, X24, X32, X41, X55, X66, X73 . Therefore, the assignments are as follows; raw material storage to location number 7, press department to location number 4, weld department to location number 2, supplier manufacturing to location number 1, mechanical test to location number 5, finish department to location number 6 and storage to location number 1 (Fig.3). Compared to classic QAP solution, it is seen that raw material storage and storage are replaced. Despite this small change, there has been a reduction of about 24% in the objective function. This means a reduction of transportation cost of 24%.

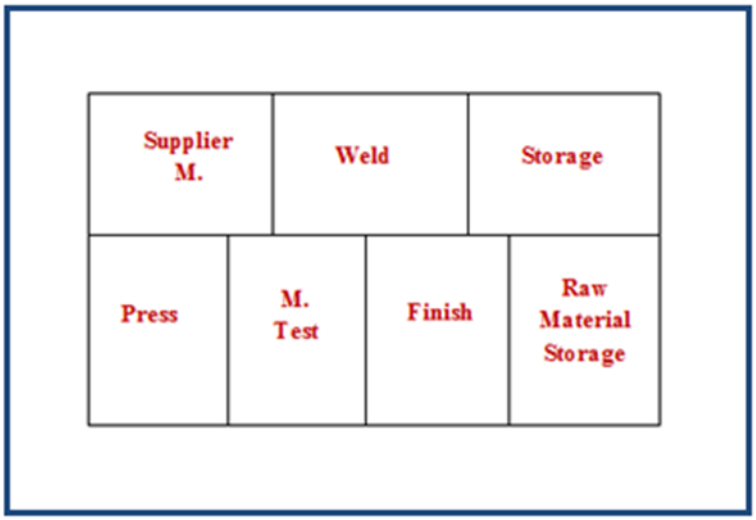


Figure 3. The new layout by solving the fuzzy weighted QAP model

3. Conclusion

The facility layout problem is one of the well-studied problems in the field of combinatorial optimization. We have implemented two different layout alternatives for a company which produces tubes in this study. We have solved the QAP formulation in GAMS mathematical programming language. The QAP and fuzzy weighted QAP formulation have been traditionally used to model the facility layout problem. However, the solution time increases exponentially with the number of facility in a facility layout problem. Therefore, it would be logical to use heuristic methods (such as genetic algorithms, simulated annealing, tabu search) for large-scale problems.

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DECISION-MAKING PROCESS OF MOTOR SELECTION FOR HUMANOID ROBOT ARM

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ABSTRACT

This research portrays the robot arm design using SolidWorks CAD for TAMU-K Humanoid Robotic Arm and develops a decision-making process for selecting the best set of smart servo motors considering weight, cost and lifting capacity. This research elaborates Profile Model, Checklist Model and Analytical Hierarchy Process for motor selection. Lastly, the LP and NLP models are used to find optimal set of motors. The results show that this decision making procedure is effective yet efficient for not only the motor selection process but the selection process in various area with many candidates.

Introduction

Robotics is the discipline concerning the robot control, design, and application in industry. While designing robot arm with multiple degrees of freedom, the Torque required at each joint to lift the assumed load varies according to the geometrical parameters of arm components, the weight of components and also the weight of preceding motors. It becomes very tedious and time-consuming process for designers to select an optimal set of motors considering multiple criteria such as cost, weight, stall torque, different brands of motors in the market, voltage ratings and range of lifting capacities at the same time.

The TAMU-K Humanoid Robot Arm as seen in the appendix was designed in 2015 [1], however, does not have a gripping mechanism integrated within it and it lifts 350 grams of weight. Hence, the version 2 was designed with addition of gripper. The CAD and FEA analysis results showed 1000 grams of load without any component failure. However, the estimated cost was higher than the original for all components of new design. So, this research begins with the cost estimation of the version 2 and lastly develops the version 3 and the version 4 by Decision-making process and Mathematical Programming models respectively. Details of the version 1 are presented in the Appendix 1.

Literature Review

Dr. Saaty gave the example of selection of best vendor through AHP considering factors such as suppliers' proximity, material cost and material quality. Ranking has been given per the importance of factors and final best one vendor which is the best combination of all factors is selected to supply material [2]. Generally, AHP technique evaluates the distinction of values between the options deliberately. The issue is separated into sub-components inside lower levels

to sort out the fundamental rationality and afterward, the priorities at every level are evaluated utilizing pairwise comparison predictions. Similar methodology has been followed in the selection of electric drive system for hybrid vehicles [4].

Another similar approach called Fuzzy AHP has been elaborated in supplier selection problem in one of the gear motor company [3]. This research suggests that fundamental AHP does exclude dubiousness for individual judgments, and thus fuzzy logic approach could be used for enhancement. At the time of solving the problem of selection of automobile purchase model [6], another methodological expansion of the AHP is implemented by concentrating on two issues. First, consolidates pairwise correlation with a spreadsheet method utilizing rating scale of 5. While doing implementation and rankings they made two groups of managers who answered about their satisfaction with automobile. Then synthesized priorities and numbers were tabulated and the consistency ratio (C.R.) is used as the decision-makers' weights. At the end, to verify the results, sensitivity analysis has been carried out. The results of sensitivity analysis matched with AHP and the best is selected as the best choice. While researching on best Fuel selection in the market, Dr. Keswani and A. Damle used AHP approach [5]. Here three significant criteria namely fuel economy, pick up of vehicle and pollution from the vehicle were considered. They put these criteria in the hierarchy of relative importance.

In Bredillet's project selection process [7], Project Saturn has a higher risk rating for its anticipated return than other projects. Since Project Mercury offers us a 16% rate of return and at the same time shows a lower risk than the current efficient frontier, it is considered as an alluring choice and a superior option than Project Saturn. The efficient frontier serves as decision-making guide by building up the limit level of risk versus reward choices that all future selection decisions must be assessed against. In the case of Invariant coordinate selection (ICS), introduced by Tyler et al. (2009) together with a one-dimensional variant called projection pursuit (PP) [9] common location measure is utilized and eigenvector decomposition is carried out to correlate the data.

In general, typical project selection models neglect the project scheduling. However, for a research on contractor selection problem based on project scheduling under uncertainty [11], it is proven that it is one of the measures of candidate selection. While validating results in Innovative Artificial Neural Network (ANN) model [10], author calculated the R^2 value to check the correlation between MLP input and output. It concluded that finest performances during training

and validation are the outcome of a repeated trial and error process, matching the properties of learning ability of the nodes and the simplification capability of the layers [10].

Methodology

From Cost and weight analysis of the version 1 and the version 2, the cost of the version 2 is $410 higher than that of the previous design. Similarly, the weight of new design is also getting increased by 177 gm. However, it lifts 1000 gm of weight which is 650 gm more lifting capacity than the version 1. As seen in comparisons of two versions, once lifting capacity is increased, the overall weight and the manufacturing cost are increased. In general, three major factors, such as cost, lifting capacity, and the weight, in a robot arm design are correlated, so this research discusses, first of all, the correlation using the regression analysis and, next, the optimal selection process, which increases the lifting capacity without increasing the cost and weight.

Regression and Correlation Analysis for Weight, Cost and Lifting Capacity

Thirty-four different sets of motors are selected from thirty-eight motors which include a variety of brands of motors with a variety of voltage ranges. The motor and set details are in the Appendix 2 and Appendix 3 respectively. Lifting capacities ranging from 400 grams to 1200 grams with an increment of 50 grams were considered. While deciding the set, motors which have less cost for calculated torque were selected. However, for deciding the second set, the priority is given for motors with lower weight. Each set has six motors for three joints of robotic arm namely shoulder, elbow and wrist, i.e. two motors on each joint.

To ensure that all three considered variables (cost of the motor, weight of motor and lifting capacities) are correlated to each other, the regression analysis has been performed using Matlab with the following hypothesis,

H_0: Two variables are NOT related.

H_1: Two variables are related each other.

The Matlab output gave the value of the correlation coefficient of respective variables. The values from the output are tabulated below.

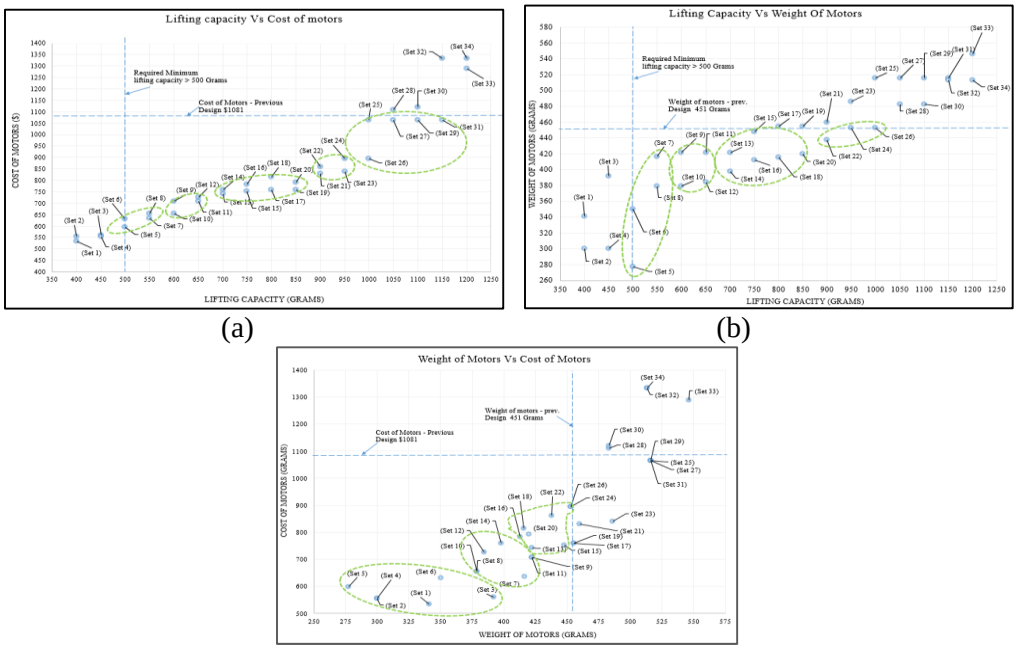
Table 1: Output values from Matlab - Correlation coefficient.

Variables compared in Matlab	Matlab Output- (R Value)
Lifting Capacity Vs Cost of motors	0.9461
Lifting capacity Vs Weight of Motors	0.9171
Weight of motors Vs Cost of motors	0.8656

From the Pearson's table, all R values pass the test, so H_0 has been rejected in each case. This proved that all the three combinations of variables are correlated. After this, scatter point graphs for 34 sets of all three combinations were plotted to analyze the data through profile model.

Profile and Checklist Models for narrowing down the candidates

In the profile model, this research sets the limits for the lifting capacity (more than 400 gm), cost (less than $1,081) and weight (less than 451 gm), so that it allows selecting a better option. All the limitations are marked on graphs in dotted lines and the sets which fall inside these boundary limits were taken into consideration for profile model. Sets which are closely related are taken into same group and best sets amongst the group were selected.



(a) (b)

(c)

Figure 4: Profile Model: (a) Lifting Vs Cost (b) Lifting Vs Weight (c) Weight Vs Cost.

Table 2 shows selected good sets from above three scatter plots and *Table 3* represents checklist model for selected good sets from profile model. From *Table 3*, it is clear that the set 5 is selected in all three graphs; the set 10 is selected in both lifting capacity vs. cost of motors and lifting capacity vs. weight of motors plots. Similarly, the set 26 is also selected in two graphs. So,

set 5, 10 and 26 are considered for the Analytical Hierarchy Process. However, all the remaining sets are selected only once and it is tough to decide which one to select for the AHP process.

Table 2: List of selected good candidates from profile model.

	Selected good candidates per Profile		
Group	L Vs C	L Vs W	W Vs C
1st	Set 5, Set 7	Set 5	Set 5, Set 1
2nd	Set 10, Set	Set 12	Set 8, Set 10
3rd	Set 19	Set 20	Set 13, Set
4th	Set 23	Set 26	-
5th	Set 26, Set	-	-

Table 3: Checklist Model for selected all good candidates from Profile Model

Set #	L Vs C	L Vs W	W Vs C
(Set 1)			X
(Set 5)	X	X	X
(Set 7)	X		
(Set 8)			X
(Set 10)	X		X
(Set 11)	X		
(Set 12)		X	
(Set 13)			X
(Set 15)			X
(Set 19)	X		
(Set 20)		X	
(Set 21)			
(Set 23)	X		
(Set 26)	X	X	
(Set 31)	X		

To decide which sets are better, the pairwise comparison based on the checklist model is followed as seen in the table 3. Five pairs of sets are formed. To form the pair, the closely related sets are considered e.g. pair 1- set 7,8; pair 2- set 11,12; pair 3- set 13,15; pair 4- set 19,20; pair 5- set 13,26. Then, two sets in pair are compared at the same time in all the three plots and if any set is getting selected in more than one plot then that set is finalized as the best set in the pair. The sets 8, 12, 15, 15 and 26 are selected as candidates from the five pairs. To select the best candidate, the Analytical Hierarchy Process has been implemented.

Analytical Hierarchy Process for Selection of Best Candidate

First of all, the pairwise comparison of all three criteria (lifting capacity, weight of motors and cost of motors) is performed with the scale of 1-9 showing the level of importance.

$$\begin{pmatrix} \text{Criteria} & \text{Cost} & \text{Lifting Capacity} & \text{Weight of motors} \\ \text{Cost} & 1 & 5 & 9 \\ \text{Lifting Capacity} & 1/5 & 1 & 3 \\ \text{Weight of motors} & 1/9 & 1/3 & 1 \\ \text{Sum} & 1.311 & 6.33 & 13 \end{pmatrix}$$

The priority vector displays the relative weights among considered criteria. The criterion with the highest priority is the cost of all motors 74.82%. The second is the lifting capacity of the arm 18.03% while the least on the list is the weight of all the motors with 7.12%. To justify that the opinion is consistent, it is required to check consistency index (C.I.) and consistency ratio (C.R.) Therefore, Consistency Index = $(\lambda_{max} - n) / n - 1 = (3.0464 - 3) / 3 - 1 = 0.0232$; Consistency

Ratio = $CI/_{RI}$. The consistency ratio is 4% which is smaller than the limit of 10% which validates that our evaluation is consistent.

To select the best set, the paired comparison of selected sets from the profile model is performed. *Table 3* shows rankings assigned for seven selected sets from profile model.

Table 3: Ranking according to the criteria.

Set #	Cost of motors	Lifting Capacity	Weight of motors
Set 5	9	1	9
Set 8	8	3	7
Set 10	6	4	7
Set 12	5	5	6
Set 15	4	6	4
Set 20	3	7	5
Set 26	1	9	3

Table 4 shows the weights of the criteria after the pairwise comparison. The set 5 with the highest sum of 0.2587 is concluded as best set with AHP technique.

Table 4: Set of motors with corresponding criteria weights.

Criteria	**Weight**	**Set 5**	**Set 8**	**Set 10**	**Set 12**	**Set 15**	**Set 20**	**Set 26**
Cost of motors	0.7482	0.3051	0.2755	0.1342	0.1009	0.0739	0.0558	0.0306
Lifting Capacity	0.1803	0.0308	0.0623	0.0748	0.1053	0.1581	0.202	0.3667
Weight of motors	0.0712	0.3507	0.1494	0.1494	0.1413	0.0657	0.0934	0.0501
Sum	1	0.2587	0.2279	0.1245	0.1045	0.0884	0.0848	0.0925

With the set 5 selection, the total cost and the weight are reduced at the same time and it achieves a higher lifting capacity. However, AHP technique and the profile model depend on the opinion of a designer or a decision maker. Here, the cost of the motor has been given the maximum priority.

LP and NLP for the optimal selection

To find the optimal set when all the criteria are equally prioritized LP and NLP models have been formulated. For formulations, the following parameters are used.

C = Cost of Motors,

L = Lifting Capacity,

W = Weight of motors

a1 = Slope of the fitting line in L Vs C plot

a2 = Y-axis intercept of the fitting line in L Vs C plot

a3 = Slope of the fitting line in L Vs W plot

a4 = Y-axis intercept of the fitting line in L Vs W plot

a5 = Slope of the fitting line in W Vs C plot

a6 = Y-axis intercept of the fitting line in W Vs C plot

b1 = Y-axis intercept of the surface in multiple regression analysis plots for C, L, W

b2 = Partial regression coefficient in multiple regression plot for C, L, W (variation in the mean response equivalent to a unit change in X1 when X2 is held constant)

b3 = Partial regression coefficient in multiple regression plot for C, L, W (variation in the mean response equivalent to a unit change in X2 when X1 is held constant)

b4 = Value of error between plotted data for multiple regression plots for C, L, W

YFIT = Z-axis value in multiple regression plot for C, L, W

X1FIT = X-axis value in multiple regression plot for C, L, W

X2FIT = Y-axis value in multiple regression plot for C, L, W

LCR = Lifting Capacity Requirement

MCR = Motor Cost Requirement

MWR = Motor Weight Requirement

Table 5 shows generalized equations for Line fitting graphs when all the above parameters are taken into consideration.

Table 5: Generalized Equations for Plots.

Plot	Generalized Equation
Lifting capacity (L) Vs Cost of Motors (C)	$C = (a1 \times L) + a2$
Lifting capacity (L) Vs Weight of Motors (W)	$W = (a3 \times L) + a4$
Weight of motors (W) Vs Cost of Motors (C)	$C = (a5 \times W) + a6$
multiple regression for L, W, C	$YFIT = b1 + (b2 \times X1FT) + (b3 \times X2FIT) + (b4 \times X1FIT \times X2FIT)$

The objective is to find optimal set of motors whose cost is less than that of previous design, which was $1,081 also lifting capacity need to be greater than 400 grams and weight of all motors used must be less than 451 grams. Figure 5 (a), (b) and (c) shows regression analysis plots for three combinations and *Figure 5 (d)* shows the graph of multiple linear regressions.

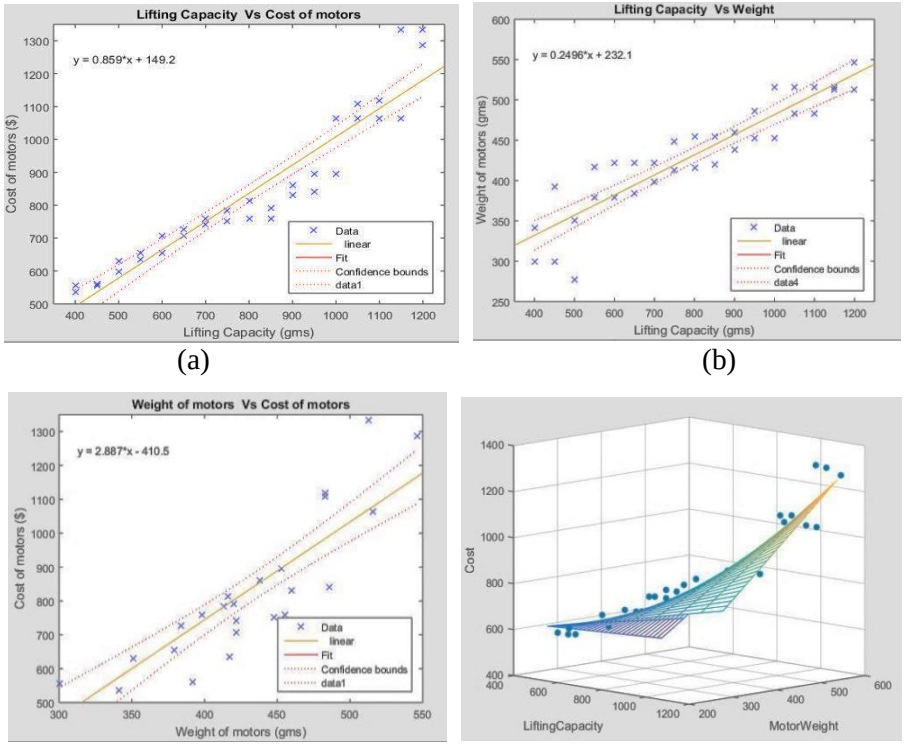


Figure 5: Line fitting plot – (a) Lifting Vs Cost, (b) Lifting Vs Weight, (c) Weight Vs Cost (d) Multiple Linear Regression 3D plot for cost, lifting capacity and motor weight.

Figure 6 shows examples of generalized LP models for all the three variable combinations.

```
Min C
s.t.
      C - (a1 × L) = a2
      L >= LCR
      C <= MCR
End
```

(a)

```
Max L
s.t.
      W - (a3 × L) = a4
      W <= MWR
      L >= LCR
End
```

(b)

```
Min W
s.t.
      (a5 × W) + C = a6
      C <= MCR
      W <= MWR
End
```

(c)

Figure 6: Generalized LP models - (a) Lifting Capacity Vs Cost of Motors (b) Lifting Capcity Vs Weight of Motors (c) Weight of motors Vs Cost of Motors.

If the objective is to find a set with cost as low as possible, minimum weight and at the same time the higher lifting capacity the problem gets converted to Non-Linear. It is clear from above study when lifting capacity increases, weight and cost increases. However, in this research, objectives are contradictory to the relations between criteria considered; the objective is to find a minimal cost with minimal weight and maximum lifting capacity. *Figure 7 (a)* shows NLP model and *Figure 7 (b)* shows its output.

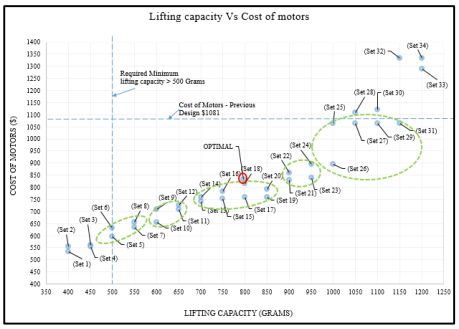
```
Min C+1/L+W
s.t.
        C - (a1 × L) = a2
        W - (a3 × L) = a4
        (a5 × W) + C = a6
End
```

```
Lifting Capacity (L) = 797.462
 Cost of motors (C) = 834.22
Weight of motors (W)= 431.146
```

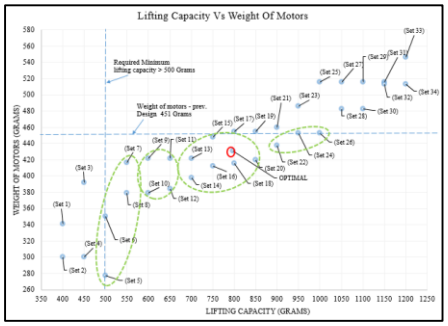
(a) (b)

Figure 7: (a) Generalized NLP model, (b) Excel Solver output for NLP model.

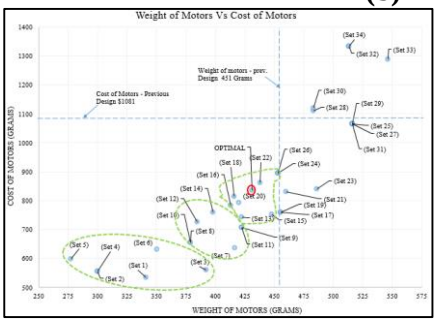
Figure 7 (b) is the optimal set. However, it is difficult to find the set of motor satisfying all the three values because motors available in the market has specific retail prices and standard specifications which do not match with these ones. Hence, to locate feasible optimal set, this point is plotted on all the graphs and the set which is closer to this point is selected. *Figure 8* shows location of Optimal set on all the three graphs.



(a)



(b)



(c)

Figure 8: Position of Optimal Set: (a) Lifting Vs Cost, (b) Lifting Vs Weight, (c) Weight Vs Cost.

From all the above graphs, it is depicted that the set 18 is the closest set to the optimal set. Appendix 4 shows the comparisons of all four versions.

Conclusion and Future Study

This research discusses the method to select the optimal set of servo motors considering the cost, weight and lifting capacity criteria using the profile model, checklist model and Analytical

Hierarchy Process. This study also developed LP and NLP models for selecting the optimal servo motors set. *Table 6* shows the consolidated comparison of all four versions of design. The version 2 gives maximum lifting capacity with addition of gripper but weight and costs are high as compared to the previous version. The version 3 based on AHP technique increases the lifting capacity by 30%, reduces the overall weight by 20% and reduces the manufacturing cost by 28% with gripper.

Table 6: Consolidated comparison of all four versions of design.

Version #	**Lifting Capacity (Grams)**	**Weight (Grams)**	**Cost ($)**
Version 1 (Previous design)	350	737	1407
Version 2 (New CAD with gripper)	1000	914	1817
Version 3 (Decision making by AHP with Set5)	500	595	1011
Version 4 (NLP with Set18)	800	733	1228

The fourth version found by the NLP increases the lifting capacity by 56% and reduces the cost by 10% keeping the weight of assembly almost equal as compared to the original design. The version 4 keeps the new gripping mechanism as well.

So, this research concludes that: 1) the proposed decision-making process of selection of motors through AHP and NLP solver is effective yet efficient; 2) this decision-making process of selection of motors is easy to follow; 3) this process could be applied in the variety of manufacturing projects where there is a need of selecting the best out of huge sets available.

This research considers only three main design criteria, which are lifting capacity, cost of motors and weight of motors. However, this decision-making process can be applied in any selection from many possible selection options, such as robot arm material selections. This research also can be extended with considering other motor related criteria such as voltage ratings, dimensions, operating angle, compatibility with other controllers and the value of factor of safety (FOS).

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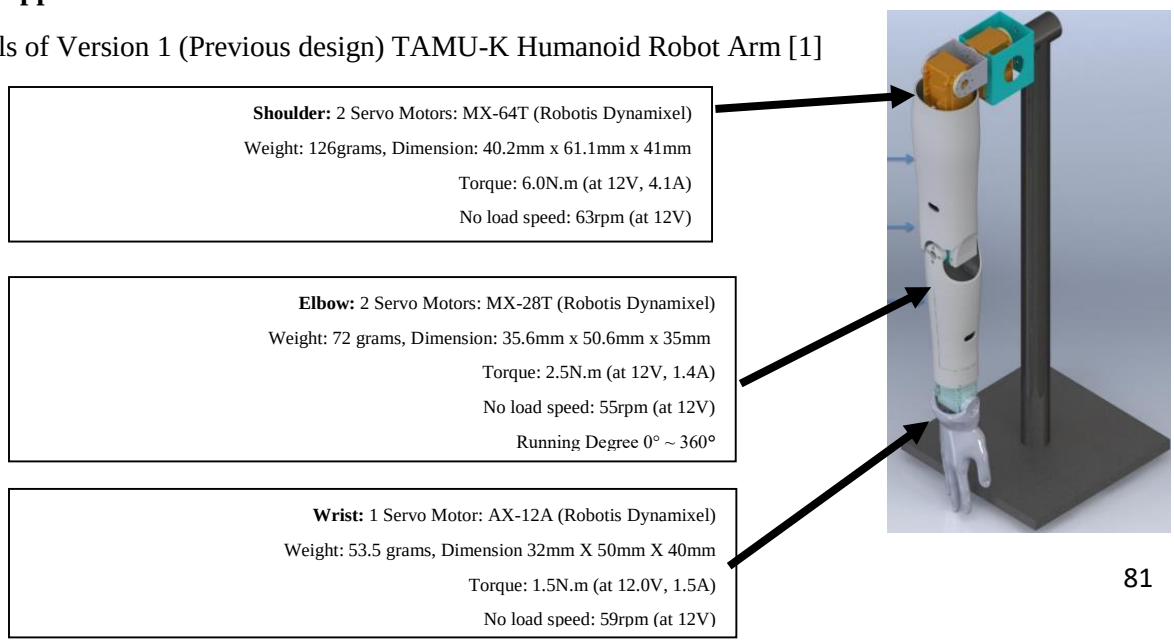
Appendix

1. Details of Version 1 (Previous design) TAMU-K Humanoid Robot Arm [1]



2. List of Thirty-Eight motors considered for selection of sets

Sr. #	Weight (grams)	cost	Motor Description	Stall Torque (Kgcm)	Sr. #	Weight (grams)	cost	Motor Description	Stall Torque
1	53	$44.90	AX-12W 12V	2	20	72	$209.90	RX-28 12V	28.3
2	16.7	$21.90	XL-320 7.4 V	3.97	21	72	$219.90	MX 28T 14.8V	31.6
3	30	$20.00	VEX IQ 12V	4.22	22	72	$239.00	MX 28AT 14.8V	31.6
4	45	$45.00	HerkuleX DRS-0101 (7.4 v)	12	23	72	$225.90	MX 28R 14.8V	31.6
5	63	$32.00	G15 Smart Serial cube(12v)	15	24	72	$209.90	RX-28 16V	37.7
6	56	$30.00	FTSC Smart Servo (6v)	15	25	123	$235.00	HerkuleX DRS-0401 (12v)	43.1
7	55	$45.00	AX-12A 12V	15.29	26	123	$235.00	HerkuleX DRS-0401 (14.8 v)	52
8	55	$44.90	XL 320 OLLO	15.3	27	125	$279.90	RX-64 15V	53
9	56	$30.00	FTSC Smart Servo (7.4v)	16.5	28	126	$299.90	MX-64T 11.1V	56
10	56	$30.00	FTSC Smart Servo (8.4v)	17	29	126	$299.90	MX-64T 12V	61
11	54.5	$94.90	AX-18A 12V	18.3	30	145	$320.00	HerkuleX DRS-0602 (12v)	62.5
12	72	$239.00	MX 28AT 11.1V	23.4	31	123	$270.00	HerkuleX DRS-0601 (12v)	62.5
13	72	$225.90	MX 28R 11.1V	23.4	32	125	$279.90	RX-64 18V	64
14	72	$219.90	MX 28T 11.1V	23.4	33	126	$299.90	MX-64T 14.8V	74
15	60	$132.00	HerkuleX DRS-0201 (7.4 v)	24	34	145	$320.00	HerkuleX DRS-0602 (14.8v)	77
16	72	$219.90	MX 28T 12V	25.5	35	123	$270.00	HerkuleX DRS-0601 (14.8 v)	77
17	72	$239.00	MX 28AT 12V	25.5	36	153	$493.90	MX-106T 11.1V	81.5
18	72	$225.90	MX 28R 12V	25.5	37	153	$493.90	MX-106T 12V	85.6
19	67	$139.90	RX-24F 12V	26	38	153	$493.90	MX-106T 14.8V	102

3. Thirty-Four sets of motors based on Excel worksheet Torque calculations

Set #	Weight of all motors (Grams)	Lifting Capacity (Grams)	Cost of motors ($)	Set #	Weight of all motors (Grams)	Lifting Capacity (Grams)	Cost of motors ($)
(Set 1)	341	400	535	(Set 18)	416	800	814
(Set 2)	300	400	556	(Set 19)	455	850	760
(Set 3)	392	450	560	(Set 20)	420	850	792
(Set 4)	300	450	556	(Set 21)	460	900	830
(Set 5)	277	500	597	(Set 22)	438	900	860
(Set 6)	351	500	631	(Set 23)	486	950	840
(Set 7)	417	550	635	(Set 24)	453	950	895
(Set 8)	379	550	654	(Set 25)	516	1000	1064
(Set 9)	422	600	707	(Set 26)	453	1000	895
(Set 10)	379	600	654	(Set 27)	516	1050	1064
(Set 11)	422	650	707	(Set 28)	483	1050	1109
(Set 12)	384	650	726	(Set 29)	516	1100	1064
(Set 13)	422	700	742	(Set 30)	483	1100	1119
(Set 14)	398	700	759	(Set 31)	516	1150	1064
(Set 15)	448	750	752	(Set 32)	513	1150	1333
(Set 16)	413	750	784	(Set 33)	546	1200	1288
(Set 17)	455	800	760	(Set 34)	513	1200	1333

4. Cost and Weight analysis of all four versions of Robot Arm design.

		Version 1 (Previous Design)			Version 2 (New DESIGN)			Version 3 (OPTIMAL DESIGN BY AHP) Set 5			Version 4 (DESIGN BY NLP Excel Solver) Set 18		
		Design without gripper, 12 V Battery, All motors Dynamixel, Lifting Capacity=350 Grams			Design with gripper, 12V Battery, All motors Dynamixel, Lifting capacity= 1000 grams			with gripper, 16V Battery, two brands of motors, Lifting capacity= 500 grams			with gripper,14.8V Battery, two brands of motors, Lifting capacity = 800 grams		
Joint	Parts	Material/Description	weight (grams)	cost ($)	Material/Description	weight (grams)	cost ($)	Material/Description	weight (grams)	cost ($)	Material/Description	weight (grams)	cost ($)
Shoulder	Motor 1	MX-64T (6.0 N.m 12V)	126.0	299.9	MX-106T (8.4 N.m 12V)	153.0	493.9	Dynamixel RX-28T 16.0 V	16.7	210.0	MX-64T 14.8V	126.0	299.9
	Motor 2	MX-64T (6.0 N.m 12V)	126.0	299.9	MX-106T (8.4 N.m 12V)	153.0	493.9	Dynamixel RX-28T 16.0 V	16.7	210.0	HerkuleX DRS-0601 (12v)	123.0	270.0
	Shoulder Bracket	Al 6063-T6	15.6	42.8	Al 2014-T4	24.3	43.4	Al 2014-T4	24.34	43.4	Al 2014-T4	24.3	43.4
	Shoulder Bottom Cover	ABS	13.6	16.6	ABS	13.6	16.6	ABS	13.58	16.6	ABS	13.6	16.6
	Shoulder Upper Cover	ABS	13.6	16.6	ABS	13.6	16.6	ABS	13.58	16.6	ABS	13.6	16.6
Elbow	Pitch To Yaw Connector	Al 6063-T6	4.0	15.8	Al 6061	7.0	42.8	Al 6061	6.95	42.8	Al 6061	7.0	42.8
	Motor 1	MX-28T (2.5 N.m 12 v)	72.0	219.9	AX-12A (1.5 N.m 12 v)	55.0	44.9	Dynamixel AX-18A 12V	55	94.9	HerkuleX DRS-0201 (7.4 v)	60.0	132.0
	Motor 2	MX-28T (2.5 N.m 12 v)	72.0	219.9	(5.3N.m 18.5 V)	125.0	279.9	HerkuleX DRS-0101 7.4 V	45	40.0	HerkuleX DRS-0101 (7.4 v)	45.0	45.0
	Humerus Frame	Al 6063-T6	24.9	43.6	Al 2014-T4	64.4	45.9	Al 2014-T4	64.4	45.9	Al 2014-T4	64.4	45.9
	Humerus Cover Outer	ABS	28.0	32.0	ABS	28.0	32.0	ABS	28	32.0	ABS	28.0	32.0
	Humerus Cover inner	ABS	28.0	32.0	ABS	28.0	32.0	ABS	28	32.0	ABS	28.0	32.0
Forearm	Forearm Bracket	-	-	-	Al 6061	41.2	44.9	Al 6061	41.24	44.9	Al 6061	41.2	44.9
	Forearm Cover Lower	ABS	41.3	43.5	ABS	41.3	43.5	ABS	41.3	43.5	ABS	41.3	43.5
	Forearm Cover Upper	ABS	20.9	24.0	ABS	20.9	24.0	ABS	20.86	24.0	ABS	20.9	24.0
Wrist	Motor 1	AX-12A (1.5 N.m 12 v)	55.0	44.9	AX-12A (1.5 N.m 12 v)	55.0	44.9	Dynamixel XL 320 OLLO 7.4V	72	21.0	HerkuleX DRS-0101 (7.4 v)	45.0	45.0
	Motor 2	-	-	-	AX-12A (1.5 N.m 12 v)	55.0	44.9	Dynamixel XL 320 OLLO 7.4V	72	21.0	XL-320 7.4 V	16.7	21.9
	Wrist Bracket	-	-	-	Al 6063-T6	16.1	43.4	Al 6063-T6	16.12	43.4	Al 6063-T6	16.1	43.4
	Four Finger	-	-	-	ABS-C01	12.6	15.0	ABS-C01	12.64	15.0	ABS-C01	12.6	15.0
	Thumb	-	-	-	ABS-C01	6.2	13.9	ABS-C01	6.24	13.9	ABS-C01	6.2	13.9
	One piece plastic Palm	ABS	95.8	55.3	-	-	-	-	-	-	-	-	-
		Total	736.6 grams	1406.4 $	Total	913.3 grams	1816.2 $	Total	594.65 grams	1010.7 $	Total	733.0 grams	1227.6 $

CATALYSTS AND BARRIERS OF ROLLING OUT ERP IN THE CLOUD: A TOE FRAMEWORK

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ABSTRACT

Cloud computing is the new buzz word in technology circles and has created new opportunities for businesses worldwide. The concept of cloud computing has gained tremendous popularity in recent times, so much so that complex information systems such as Enterprise Resource Planning (ERP) systems are being implemented using this technology. This innovative technology offers myriad of benefits to businesses specifically those which fall in the category of Small and Medium Enterprises (SMEs); however there are several barriers obstructing its diffusion at a large scale. This study is an attempt to highlight the catalysts and barriers of cloud ERP adoption. A systematic literature review is conducted to achieve this objective. Technology, organization and environment (TOE) framework is used for categorizing each factor reported either as a motivator or a barrier in the literature. The findings are of significant importance for the SMEs, ERP vendors and policy makers.

Keywords: ERP Cloud, SaaS ERP, Technology Adoption, Barriers, Motivators, TOE

1. Introduction

The concept of full-scale enterprise resource planning (ERP) system surfaced in early 1990s. The idea behind ERP system was to offer a single data repository connected to an array of software modules with an overall objective of integrating all key processes related to several functional divisions within an organization (Peng & Gala, 2014). Data integration and increase in operational efficiency are generally considered the key motivators of ERP adoption (Kamhawi, 2008). Other advantages of ERP systems reported by the researchers are flexibility, reliability of data, smooth flow of information and transparency (Oliver et al., 2005). There are different modules related to an ERP system each focusing on a specific business process that include finance, human resource management, project management, marketing, quality management, assets accounting and sales and distribution. Different ERP vendors have played an important role in the popularity of these systems worldwide. Although the list of ERP vendors is very long SAP, Oracle, Microsoft, Infor, Epicor, QAD and Sage are the major players in that list.

The earlier versions of ERP required on-premise installation which was characterized by high costs, large sized implementation and long implementation time (generally in the range of 12-36 months). ERP hosted solutions emerged in early 2000s in which the software is installed on firm's computers, however the computing platform is managed off-site. The capital costs involved in hosted ERP solution were lower as compared to on-premise implementation as well as the implementation time was reduced within a range of 9-18 months. The latest development in ERP implementation is a cloud based ERP system in which ERP system is implemented via cloud while the end-users access it through a web-browser. This third option i.e., cloud ERP is the most cost effective and can be implemented in a short span of 4-8 months (Utzig, Holland, Horvath & Manohar, 2013). The software license cost is to paid upfront in case of in-house and hosted implementation models, while it is to be paid in the form of monthly subscription in cloud ERP model (Roach, 2013).

Cloud computing is a novel way through which organizations can fulfill their software requirements wherein computing resources are offered as a service rather than a product (Kuada, Adanu & Olesen, 2013). Cloud computing compared to traditional computing offers several revolutionary advantages such as lower cost, speedy access to markets and opportunities to create new sources of value (Forrest & Barthold, 2009). A comprehensive definition of cloud computing is offered by the National Institute of Standards and Technology (NIST) of U.S. Department of Commerce, according to which the five essential characteristics of cloud computing are resource pooling, on-demand self-service, rapid elasticity or expansion, broad network access and measured service. It also lists three "service models" (software, platform and infrastructure), and four "deployment models" (private, community, public and hybrid) that together categorize ways to deliver cloud service (Mell & Grance, 2011).

In cloud computing everything is considered a service (i.e., XaaS) e.g., Software as a service (SaaS), Platform as a service (PaaS) and Infrastructure as a service (IaaS) (Xu, 2012). In SaaS model, organizations can access provider's application running on a cloud infrastructure on rental basis and it is this category to which cloud ERP belong. Google Apps and Salesforce CRM are the examples of this model. PaaS is geared towards offering a middleware to firms to

incorporate the complete development cycle that might cater testing, hosting and deployment and web applications. Google App Engine and Apache Stratos are the examples of PaaS. The third model IaaS is mostly targeted towards administration which offers the needed processing power and storage space to the clients. Windows Azure and Google Compute Engine are examples of IaaS. As far as the cloud deployment models are concerned the public cloud offers access to general public and is mostly owned and managed by a public service entity such as a government or university, while a private cloud offers access to a single client. The community cloud offers services to a specific community of organizations having common interests; whereas hybrid cloud is a composition two or more deployment models (private, public or community) in which more sensitive data is hosted privately, whereas the less sensitive data is stored on public cloud.

Cloud ERP, as the name indicates, is a combination of cloud and ERP functionalities. Different researchers have coined different terms for this combination: real-time ERP, service-based ERP, ERP III and cloud-based ERP (Saeed et al., 2012). It is an innovative enterprise system (ES) approach which offers the functionalities of on-premise ERP along with unique features of cloud computing. Cloud ERP is becoming a popular choice and Lin & Chen (2012) reported a notable shift from traditional ERP to this emerging phenomenon. This popularity of cloud ERP is negatively affecting the sales of traditional ERP. Ricadela (2014) reported that SAP's first quarter sales and earnings were less than the estimated value mainly due to increase in sales of cloud ERP systems.

A review of studies on cloud ERP adoption highlights the fact that the concept in still at an infancy stage, specifically in the developing countries, which makes it extremely important to explore the factors that could promote this innovative technology or the barriers that should be removed to promote its adoption. It is expected that this study will contribute to existing literature on the topic of cloud ERP adoption as well as bring to light key factors promoting or inhibiting its adoption which will be useful for the practitioners as well as policy makers. The researcher reviews the existing literature on the topic of cloud ERP adoption and highlights the key drivers and barriers of this novel technology.

The paper is organized as follows: research methodology is discussed in section 2, followed by a discussion of factors affecting cloud ERP adoption in section 3. The conclusions and

recommendations are presented in section 4 and finally the limitations and directions for future research are outlined in section 5.

2. Methodology

This study is basically a review of existing literature available on the topic of cloud ERP adoption. A systematic literature review approach was adopted in this study which is based on rigorous review of research results (Kitchenham, 2004; Okoli & Schabram, 2010). The objective of the systematic literature review here is to pinpoint the factors that promote or inhibit the adoption of cloud ERP. For the purpose of gathering data, relevant research articles were downloaded from different academic journals from several databases that include Science Direct, Emerald, EBSCO, ACM Digital library and IEEE Xplore Digital library. Articles were searched using different keywords such as “cloud ERP adoption And/or barriers” and “Saas ERP adoption And/or barriers”. The selected articles were further scrutinized and only those articles were shortlisted for the review in which motivators and barriers of cloud ERP were discussed.

Furthermore, Technological, organizational and environmental (TOE) catalysts and barriers were identified using TOE framework proposed by Tornatzky and Fleischer (1990). The TOE model is considered to have a broad applicability across several technological, industrial, and national/cultural contexts (Sœdberg & Haddara, 2016) and is also used by several other researchers who conducted studies in the similar domain (e.g., see Qian, Baharudin, & Kanaan-Jebna, 2016). The results of the review are presented in next section.

3. Factors Affecting Cloud ERP adoption in Developing Countries

As mentioned earlier, TOE framework was followed in identifying the main motivators and barriers of cloud ERP adoption. Review of existing literature on the topic brings forth the following technological, organizational and environmental factors considered crucial for adoption of this innovative technology by different researchers:

3.1 Technological Factors

Several technological factors have been pointed out by different researchers that could play a crucial role in cloud ERP adoption. Some of these factors are the motivating factors that are attracting more and more organizations towards cloud ERP, while others are inhibitors which must be addressed to attract even more organizations towards its adoption. Technological motivators and barriers are discussed in the next section.

3.1.1 Technological Motivators

Since cloud ERP offers the advantages of both the cloud technology as well as ERP functionalities, the list of technological motivators is quite long. However, the following are the most commonly cited ones:

Cost Savings

Cloud ERP is a cost effective solution when compared to traditional on-premise or hosted ERP systems. The cost savings in this model occur mainly due to reduced IT infrastructure and IT related manpower (Lenart, 2011). The prominent feature of cloud ERP system is the minimal upfront cost (Ambrust et al., 2011). Moreover, the maintenance and up-gradation of the system are also the responsibility of the vendor in SaaS model. The organizations are saved from any additional costs occurring due to damage to IT infrastructure and hardware installed at the vendor's site. Energy, maintenance, up-gradation/configuration and IT staff cost savings are the key advantages of Cloud-based ERP (Castellina et al. 2011, Marston et al. 2010).

Shorter Implementation Time

Another technological motivator is shorter implementation time offered by cloud ERP systems compared to traditional ERP systems (Duan et al., 2013, Zhong & Rohde, 2014; Lechesa et al., 2012). On-premise ERP system can take several months and even years before it is fully implemented whereas cloud ERP system can generally be installed and fully implemented within 4-8 months (Utzig et al., 2013).

Availability of Reliable Vendors

Presence of reliable vendors in the local market is another technological motivator of cloud ERP adoption. The success stories of local clients can be motivating factor for others to fall in line. Reputation, brand image and long standing history of vendor are considered important determinants of SaaS ERP adoption by Seethamraju (2013). Internationally reputed ERP vendors such as SAP, Oracle and Microsoft are available and offering their products in most of the developing countries, but one of the key issues with their offered ERP solutions is the high cost which makes it beyond the reach of majority of private sector organizations in those countries. This creates an opportunity for local ERP vendors who generally are offering these functionalities at a much lower cost. Locally developed ERP solutions are generally preferred by those businesses that have low budget and lesser automation requirements.

Ease of Managing Upgrades

In case of cloud ERP model upgrades are managed by the vendors (Saeed et al., 2012). On the other hand, in traditional ERP all such upgrades are to be managed by the clients, which generally are time consuming and cumbersome and sometimes could result in change in a business process or loss of customization made in original ERP package. It is due to these reasons some companies using traditional ERP system opt not to upgrade their existing system. SaaS providers, in many cases, offer superior quality backup routines, fallback and recovery procedures, conditioned power etc. compared to in-house ERP systems (Scavo et al., 2012).

Flexibility

Technically cloud ERP systems are much more flexible than traditional ERP systems since ERP vendors offer bolt-on applications useful for analysis, collaboration and financial management that can be easily downloaded from the vendor’s web-based app store. Cloud ERP systems are particularly suitable for fast growing SMEs since they can extend their existing ERP system conveniently side by side their growth due to which increasing costs of ERP system are easily absorbed by the increasing revenues. Cloud ERP enhances the organizational flexibility to a great extent by offering on-demand IT resources. It is a very suitable model for accommodating fluctuating usage of IT resources, since the clients are charged according to the amount of IT

resources consumed (Mell and Grance, 2009). Moreover, businesses get access to instant and virtually infinite supply of IT resources, which offers rapid scalability and elasticity, besides solving the issue of over- or under-provisioning of IT resources generally faced in case of on-premise ERP systems (Buyya et al., 2009).

Scalability

Scalability is also reported as a technological motivator for cloud ERP adoption by different researchers (e.g., see Salum & Rozan, 2015; Appandairajan et al., 2012; Saeed et al., 2012; Elragal & Kommos, 2012). In cloud ERP model, the concepts of resource pooling and resources on-demand makes the ERP infrastructure highly elastic (Scavo et al. 2012).

3.1.2 Technological Barriers

The literature review indicates that organizations considering cloud ERP generally face the following technological barriers:

Switching Costs

Generally businesses have made some IT investment to fulfill their information needs for smooth business operations. Switching their existing system to an ERP system could pose compatibility issues due to which many organizations opt not to go for this change. The decision to switch to cloud ERP system is particularly difficult for organizations who have already invested reasonable amount on employees' training for on-premises ERP system (Saeed et al., 2012).

Complex Integration

Those organizations that seek to integrate cloud ERP into their existing IT infrastructure face interoperability issues. Integrating home-grown applications and existing application portfolios with a cloud supported ERP system has noticeable constraints (Karabek et al. 2011).

Difficult Customization

There is generally less room for customization in case of a cloud ERP system as compared to an on-premise or hosted ERP system (Scavo et al. 2012). However, the issue of customization is more pertinent for large scale businesses compared to the SMEs.

Security and Trust Issues

Security and trust is also considered a technological barrier by several researchers (e.g., see Saeed et al., 2012; Lechesa et al., 2012; Yeboah-Boateng & Essandoh, 2014, Weng & Huang, 2014; Salum & Rozan, 2016). Security is one of the main issues faced by the companies considering to adopt cloud ERP, specifically security in access control, identity management and privacy (Takabi et al,. 2010). Compared to an on-premise ERP, organizations using cloud ERP have limited control over the security. Cloud based ERP systems are potentially more exposed to attacks and hazards (Zissis and Lekkas, 2012). It is mainly due to the data security and privacy concerns organizations are often hesitant to adopt this technology (Kaufman, 2009; Rabai et al., 2013).

Low Internet Bandwidth

Cloud ERP is implemented via internet hence the availability of appropriate internet bandwidth is considered a must for its smooth functioning. Cloud ERP users will face difficulties in communication and transfer of data in case the internet bandwidth is low or technically inappropriate (Salleh, Teoh and Chan, 2012). The minimum recommended downloading speed for smooth functioning of this model is between 10-15 Mbps.

Unreliable Internet Connectivity

Another technological barrier generally faced in case of developing countries is the intermittent internet connection (Navaneethakrishnan, 2013) which could create problems in smooth operation of cloud ERP. A stable, reliable and predictable internet connection is required to access the web based services in SaaS model (Johansson & Ruivo, 2013). Poor internet access and connectivity was reported a significant barrier for cloud computing adoption by Yeboah-Boateng & Essandoh (2014).

Poorly defined Service Level Agreements (SLAs)

It is difficult to draft SLAs that appropriately address all the concerns of the clients especially in case of adversaries (Kuyoro et al. 2011). Since all the aspects of confidentiality and integrity are not covered in a SLA there's always a room for unclear damage liability (Rong et al., 2012). The consequences of poorly designed SLAs are obvious: the service provider will deny his liability whenever any conflict arises (Marston et al., 2011). A common observation is that presently SLAs does not offer sound protection of clients' interests.

3.2 Organizational Factors

The most prominent organizational motivating and inhibiting factors found in the literature are discussed in the next section.

3.2.1 Organizational Motivators

The following are the most cited organizational motivators of cloud ERP adoption:

Perceived Advantages of Cloud ERP

Organizations will consider investing in a new technology only if they are convinced it will bring positive return on investment (ROI). Advocates of ERP system claim it will result in increase in operational efficiency and better communication among the employees, suppliers and customers. Flexibility, lower initial costs, scalability and pay per use are the notable advantages of cloud computing (Dwivedi and Mustafee, 2010). Cloud ERP brings to table the advantages of both the ERP and cloud computing.

Top Management's Support

Top management's attitude towards IT in general and cloud ERP in specific is another organizational feature that could influence cloud ERP's adoption (Low et al., 2011; Baotend and Esscondah, 2014). If CEO of an organization is convinced that investment in this innovative technology will fetch positive results in terms of operational efficiency and relationship management (whether it be among employees, suppliers and customers) the prospects of cloud ERP adoption will increase.

Affordability

ERP adoption is a costly affair and organizations need to have financial muscles to handle it. An organization can consider adopting this cutting edge technology only if it has the budget needed to invest in required hardware, software and training of employees.

Focus on Core Competency

Cloud ERP is one approach to enable businesses to focus on their core competency (Duan et al., 2013) rather than spending too much time and energy on technology glitches. All the maintenance, troubleshooting and upgrades in SaaS model are the responsibility of ERP vendor, therefore the client has more time to focus on its core business.

3.2.2 Organizational Barriers

The barriers obstructing the cloud ERP at the organizational level are discussed in the next section.

Resistance to Change

The biggest organizational barrier in cloud ERP implementation is the resistance to change or maintenance of status quo (Boatend & Esscondah, 2014, Johansson, Alajbegovic, Alexopoulo & Desalermos, 2015). An ERP implementation is bound to bring changes in certain business processes as well as transparency of information which might not be appreciated by some in the organization and ultimately they are the one who will resist implementing it.

Lack of Availability of Skilled IT Staff

Another organizational barrier is the lack of availability of skilled IT staff. The success of any IS depends to a great extent on the use and satisfaction of end user; the availability of trained and competent IT staff can help in achieving this goal easily and smoothly. Lack of internal expertise and knowledge is considered high level barrier of cloud ERP adoption by Yeboah-Boateng & Essandoh (2014).

3.3 Environmental Factors

The businesses don't operate in isolation rather they are greatly influenced by the surrounding environment. There is significant impact of overall economic condition of the country, business environment, society and government policies on the business firms. The impact of some of the important environmental factors on cloud ERP adoption is discussed next.

3.3.1 Environmental Motivators

The main environment motivators of cloud ERP adoption pointed out by different researchers are discussed below.

Competitive Pressure

Competitive pressure is one of the environmental motivator that could force the organizations to adopt cloud ERP system (Saeed et al., 2012). It is a well established fact that a company without appropriate IT cannot compete with a company using state of the art technology.

Trading Partner's Pressure

In present day business environment companies sometimes are pushed to adopt certain technology by the trading partner's pressure (Gutierrez, Boukrami & Lumsden, 2015). For example Walmart's decision to use RFID tags forced its suppliers to use the same technology.

Government Support

Government's role in adoption of IT is also very important. Positive support from government in terms of relaxation on import duties, tax incentives and regulations supporting use of technology can help companies in using IT in their businesses. Government's support in terms of financial and human capital and supportive regulations for data security can positively promote the adoption of cloud ERP (Salum & Rozan, 2016).

3.3.2 Environmental Barriers

The following are the prominent environmental barriers pointed out by different researchers:

Lack of Early Adopters

Lack of early adopters could be an issue in diffusion of a new technology such as cloud ERP as was reported in a study conducted by Saeed et al. (2012). Success stories of early adopters motivate laggards to fall in line.

Lack of Proper IT Infrastructure

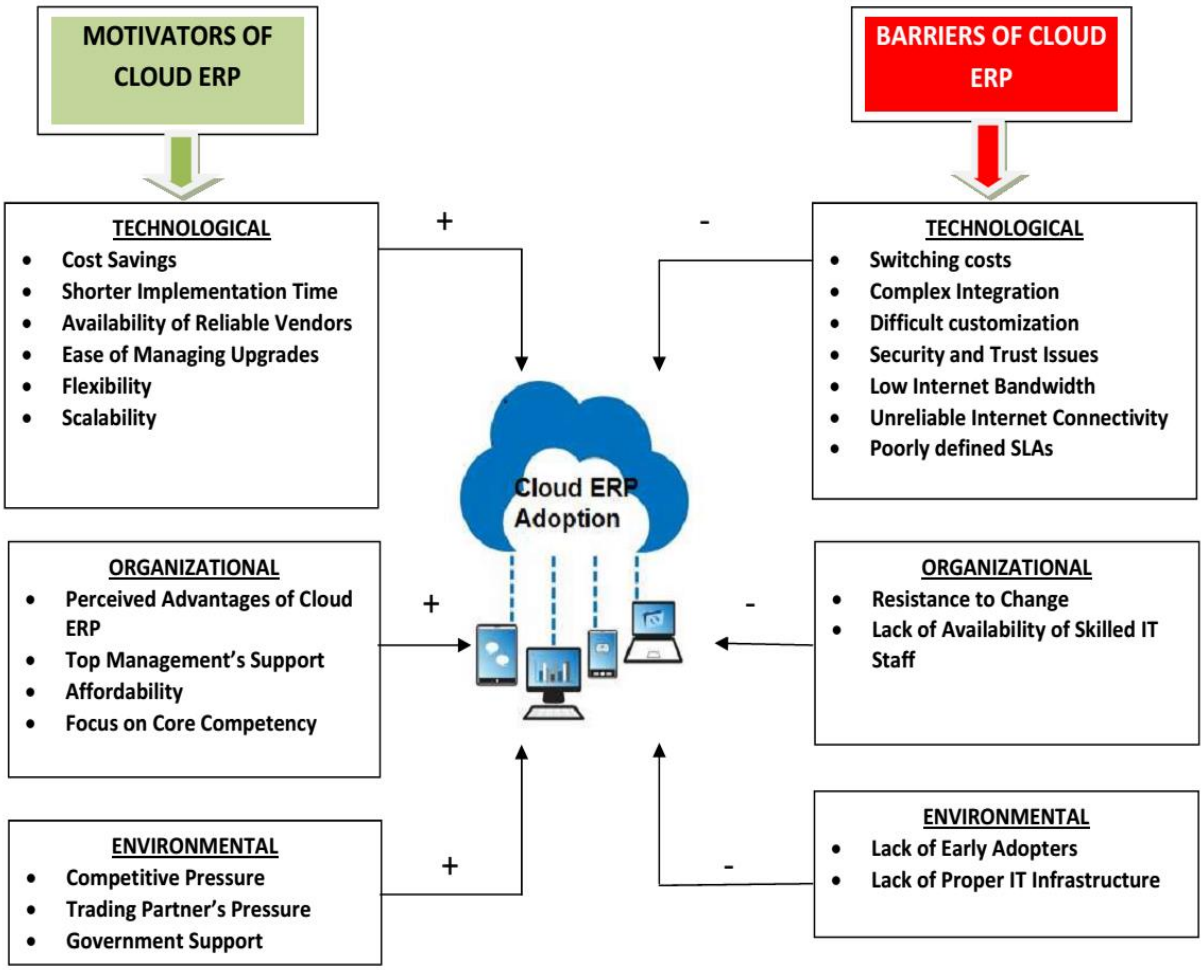
Lack of proper IT infrastructure could also serve as a barrier in adoption of a technology (AlBar & Hoque, 2015). The infrastructure needed for Cloud ERP adoption is uninterrupted power supply and internet with suitable bandwidth, both of which can be an issue in developing countries.

4. Conclusion & Recommendations

Prominent motivators and barriers of cloud ERP adoption highlighted by the literature review are presented according to TOE framework in figure 1. The concept of cloud ERP is gaining popular in developed as well as developing countries of the world. Cloud ERP vendors can specifically target the SMEs, since this model is more appropriate to meet their requirements. They should contact the top management of SMEs and convince them about the perceived advantages of these systems and expected ROI. Moreover, they should address the privacy and data protection concerns of the organization to gain their trust. The businesses can be convinced that the cloud ERP vendor will take care of all of their IT needs/issues, hence the client can spend more time and energy on its core business.

Those organizations which have decided to adopt this technology should focus on drafting comprehensive SLAs to ensure their rights and interests are safeguarded under all circumstances. Moreover, they need to train and educate their employees to get them maximum utility from this innovation as it will minimize the resistance to change as well. The role of government is also crucial in promotion of this technology, since it can assist in providing the needed IT infrastructure – especially reliable internet connection and appropriate internet bandwidth. Moreover, government can support in the diffusion of this technology by encouraging favorable legislation to protect the rights of clients using this technology.

Figure 1 : TOE Factors Affecting Cloud ERP Adoption



5. Limitations of study & Future Directions

The main limitation of this study is that it is based only on review of existing literature on the topic of cloud ERP adoption. The findings of this study can further be validated by using different qualitative and quantitative research techniques such as focused group discussions/interviews and field surveys. Country and region specific studies can further increase the utility of this study for various stakeholders such as business firms, ERP vendors and government policy makers.

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IMPACT OF REAL TIME EVENTS ON THE ATC-BASED HEURISTIC ALGORITHMS FOR DYNAMIC SCHEDULING OF BURN-IN OVENS WITH NON-AGREEABLE RELEASE TIME AND DUE-DATES

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ABSTARCT

Many researchers highlighted that the dynamic nature, due to dynamic arrival of jobs as well as real time events associated with jobs and/or resources, of manufacturing makes rescheduling essential, particularly in scheduling discrete processor, in today's complex production environment. However, this study proofs both empirically and statistically that rescheduling is not required to obtain efficient schedule when there is efficient algorithm(s) for dynamic scheduling of batch processing machine, particularly burn-in oven in the testing area of semiconductor manufacturing, when real time events associated with jobs and/or resources happened while making scheduling decision.

Keywords: Burn-in Oven, Dynamic Scheduling, Real-Time Events, Semiconductor Manufacturing

Introduction

Scheduling of a Burn-in Oven (BO) problem, motivated by burn-in operations in the final testing stage of semiconductor manufacturing, was first introduced and studied by Lee *et al.* (1992). Burn-in oven is used to heat-stress test the IC chips. Accordingly, in reality, every customer's jobs (i.e. ICs), which are processed in burn-in oven, are characterised by pre-specified minimum exposure time (that is, processing time) in burn-in oven (p_j), number of boards required to accommodate the customers orders (W_j) before placing into the burn-in oven, available time, called as release time in scheduling literature, for processing in burn-in oven (r_j) and this can be obtained easily as the shop-floor is computerised for tracking and controlling the processes, and step-due date, which is generally called due-date, for the job to complete the burn-in operation (d_j). Furthermore, the release time (r_j) and due-date (d_j) are non agreeable (that is, $r_i < r_j$ not-implied $d_i < d_j$). In addition, in the real life various unexpected job related real time events such as rush job, due-date change, early/late arrival of job, change in job priority, job cancellation, etc., and/or resource related real

time events such as machine breakdown, operator illness, tool failure, shortage of material, defective material, etc. will occur in addition to the dynamic arrival of jobs. From the literature, it is observed that, the earlier studies on dynamic scheduling of burn-in oven consider only future arrival of jobs (that is different release time data) and no study considering real time events.

A burn-in oven is a batch processor (BP), which can simultaneously process several jobs as long as the total size of jobs (measured in terms of number of boards required to place them in boards) in a batch do not exceed the machine capacity (measured in terms of number of maximum boards and generally it varies from 6 to 12 boards). In general, the jobs assigned to a batch can stay in an oven longer than its minimum required processing time in it and due to this, the processing time of a batch is represented by the longest processing time required among all the jobs in the batch. Once a batch is being processed, no jobs can be removed from or introduced into the BP until the process is complete. The minimum processing time required in burn-in oven is longer compared to other operations of final testing and the cost of equipment: burn-in oven is very costly, the batching and scheduling of jobs for the single batch-processing machine problem is highly important and this affect the production rate [Mathirajan and Sivakumar, 2006] as well as meeting the customer due-date.

This paper considers a single Burn-in Oven (SBO) with all the problem characteristics discussed here to address the impact of JR-RTE on the proposed dynamic scheduling algorithms for SBO. Considering the three-field notation of Graham et al., [3] the problem addressed in this study is denoted as "1/batch, dynamic job arrival, non-identical job-sizes, non-identical processing times, non-agreeable release times and due-date, job and/or resource related real time events/ TWT, TWCT, Cmax" with the following assumptions:

- DS-SBO problem is deterministic. That is all the data related to p_j, r_j, s_j, d_j are known a priori.
- Every job must be processed in burn-in oven and the machine can process several jobs in a batch, and the total size of jobs (that is number of boards) in a batch must be less than or equal to the machine capacity (B).
- Splitting of jobs between different batches is not allowed.

- Once the processing of a batch is initiated, it cannot be interrupted and other jobs cannot be introduced into the oven until process is complete.

Due to the computational intractability in obtaining exact solution for DS-SBO, a few variants of simple greedy heuristic method (GHM), based on due-date based dispatching rules, which are extensively used in scheduling various operations in semiconductor manufacturing, are proposed to dynamically scheduling single burn-in oven (DS-SBO) with the scheduling objective: TWT, TWCT, and Cmax.

In the following section, a closely related review on dynamically scheduling single burn-in oven is reviewed. Section 3 presents the proposed variants of GHM for DS-SBO. A research hypothesis to study the impact of JR-RTE is discussed in Section 4. Section 5 discusses the testing of the proposed research hypothesis. Finally, Section 6 discusses the conclusions and future research.

Closely Related Literature Review

Batch processing machines (BPM) are encountered in many discrete parts manufacturing industry. Various research works addressed in the literature on BPM scheduling are comprehensively reviewed in Potts *et al.* (2000), Mathirajan and Sivakumar (2006), and Monch and Fowler (2011). Particularly, since 1992, there is a rich amount of literature available on scheduling of burn-in oven. Various research addressed in the literature on scheduling of burn-in oven is classified into static scheduling and dynamic scheduling. In the case of dynamic scheduling the important real-life information on the available time of the job (called as release time in scheduling) for processing in burn-in oven is considered, whereas in the static scheduling the available time of the job is considered to be the same (that is all jobs are available at time equal to 0) for all jobs. As the research considered in this study is related dynamic scheduling, the research studies addressing the static ones [Dupont and Ghazvini (1997), Zhang *et al.* (2001), Jia and Leung (2014)] are not reviewed.

Many studies [Lee *et al.,* (1992), Li and Lee (1997), Qi and Tu (1999), Wang and Uzsoy (2002), Liu *et al.,* (2007), Chou *et al.,* (2008), Liu *et al.,* (2009), Mathirajan *et al.,* (2010), and Wang (2011)] addresses the scheduling of burn-in oven considering ‘future arrival of jobs’ while

scheduling decision is taken and in the literature these studies are called as dynamic scheduling. In the reality, in addition to considering the 'future arrival of jobs', the real time events related to jobs and/or resources, may occur, while scheduling decision is taken for Burn-in operation. Recently Mathirajan and Vimalarani (2015) studied the impact of resource related real time events on the proposed dynamic scheduling of single Burn-in Oven. Other than that there is no study considering real time events related to job, and/or resources along with 'future arrival jobs' in scheduling a single burn-in oven. This study makes an attempt to study the impact of job and resource related events (JR-RTE) on the dynamic scheduling algorithm presented in Mathirajan and Vimalarani (2015) considering the scheduling objectives: TWT, TWCT and Cmax.

Greedy Heuristic Method (GHM) for DS-SBO

Due to the computational difficulties [Mathirajan and Vimalarani (2015)] in obtaining exact solution for dynamic scheduling of single burn-in oven with non-agreeable release time and due-date, a simple greedy heuristic method based on different ATC based dispatching rules, which are widely used in practice due to their ease of implementation, robustness to shop-floor disruptions and low computational burden (Hildebrandt *et al.,* 2010), presented in Mathirajan and Vimalarani (2015) is considered. The step-by-step procedure of GHM, considered in the paper, is as follows:

Step 1: Capture the next availability time of the BPM and all the characteristics of the jobs available in front of the BPM.

Step 2: Calculate the **ATCIndex,** using ATC rule, for every job.

Step 3: Sort the list of available jobs in-front of the BPM in **decreasing** order of the **ATCIndex**

Step 4: Select a set of jobs from the top of the list of available ordered-jobs until batch size constraint is satisfied to the maximum extent and form a batch **B**.

Step 5: Compute starting time, processing time, completion time, weighted completion time and weighted tardiness of the batch **B**.

Step 6: Allocate the batch B to the BPM.

Step7: Compute total weighted tardiness (TWT), total weighted completion time (TWCT), and maximum completion time (Cmax) of allocated batch(es)

Step 8: Update the work in process of the jobs by excluding the jobs allotted to the batch **B** and processed in the BPM. Also, update the next availability time of the BPM. Finally make the batch **B** as empty set.

Step 9: Repeat Step 2 until all jobs are scheduled.

Nine variants of the proposed GHM are created based on different ATC dispatching rules [presented in Table 1], called as nine variants of GHM-ATC.

A Research Hypothesis to study the Impact of JR-RTE on GHM-ATC for DS-SBO

In the literature, dynamic scheduling with real time events is termed as dynamic real time scheduling (DRS). The analysis of the literature clearly indicates that there is only one study by Mathirajan and Vimalarani (2015) in DRS of Burn-in Oven and this study indicates that any efficient algorithm for dynamic scheduling algorithm of SBO is sufficient for DRS of SBO whenever resource related real-time event happens while taking the scheduling decision. That is, this study proved empirically and statistically the research hypothesis that adjusting the data on 'next availability time of the Burn-in Oven for scheduling' is sufficient whenever any resource related real time event happens. In this study, the same hypothesis is generalized considering the occurrences of any types of real time events along with considering future arrival of jobs. Accordingly, the following research hypothesis is proposed:

> *Modifying appropriately the work-in-process (WIP) data and/or the availability time of the burn-in oven depending upon the occurrence of job and/or resource related real time events respectively by utilizing the existing computerized tracking system in the shop floor is sufficient when there is an efficient algorithm for dynamic scheduling of burn-in oven considering only future arrival of jobs, and developing rescheduling algorithm or modifying the current algorithm whenever any types of real time events occur is not required for scheduling burn-in operations.*

Table 1: Variants of proposed GHM based on ATC dispatching rule

Variants of GHM	ATC Rule	Source
1	$\left(\frac{W_j}{P_j}\right) * \exp^{-\left[k*\left(\max(0,d_j-P_j-t)\right)/\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}$	Morton and Rachamadugu (1983)
2	$\left(\frac{W_j}{P_j}\right) * \exp^{-\left[\max(0,d_j-P_j-t)/k*\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}$	Balasubramanian *et al.* (2004)
3	$\left(\frac{W_j}{P_j}\right) * \exp^{-\left[\max\left(0,d_j-P_j+(R_j-t)\right)/k*\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}$	Monch *et al.* (2006)
4	$\left(\frac{1}{P_j}\right) * \exp^{-\left[\max\left(0,d_j-\left(P_j+\max(P_j,t)\right)\right)/\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}$	Farhad and Laya (2007)
5	$\left(\frac{1}{P_j*d_j}\right) * \exp^{-\left[\max\left(0,d_j-\left(P_j+\max(P_j,t)\right)\right)/\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}$	
6	$\left\{\left(\frac{1}{P_j}\right) * \exp^{-\left[\max\left(0,d_j-\left(P_j+\max(P_j,t)\right)\right)/\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}\right\} * W_j$	Modified version of Farhad and Laya(2007)
7	$\left\{\left(\frac{1}{P_j*d_j}\right) * \exp^{-\left[\max\left(0,d_j-\left(P_j+\max(P_j,t)\right)\right)/\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}\right\} * W_j$	
8	$\left(\frac{W_j}{P_j}\right) * \left(\exp^{-\left[\max\left(0,d_j-P_j-t+(R_j-t)^{+}\right)/k*\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right]}\right)$	Li *et al.* (2010)
9	$\left(\frac{W_j}{P_j}\right) * f(W_j, T_j) * \exp^{-\left[\left(d_j-P_j-t+(R_j-t)^{+}\right)^{+}/\left(k*\left(\frac{1}{N}*\sum_{j=1}^{N} P_j\right)\right)\right]}$ Where $f(W_j, T_j) = 1$ if $(RTB_b+P_j-d_j) \leq 0$; $W_j / (RTB_b+P_j-d_j)$ otherwise	Vimala Rani and Mathirajan (2013)

For testing the above proposed research hypothesis, this study proposes the following measurable research hypothesis for each of the scheduling objectives:

$H1_0$: There is a significant difference on the relative efficiency between each of the nine **proposed variants of GHM-ATC,** and the corresponding **adjusted GHM-ATC** with JR-RTE for DS-SBO while minimizing the **TWT**.

$H2_0$: There is a significant difference on the relative efficiency between each of the nine **proposed variants of GHM-ATC,** and the corresponding **adjusted GHM-ATC** with JR-RTE for DS-SBO while minimizing the **TWCT**.

$H3_0$: There is a significant difference on the relative efficiency between each of the nine **proposed variants of GHM-ATC,** and the corresponding **adjusted GHM-ATC** with JR-RTE for DS-SBO while minimizing the **Cmax**.

The alternative hypothesis for each of the above three measurable research hypothesis (that is, null hypothesis) is the negation of the corresponding null hypothesis.

Testing of the Proposed Research Hypothesis

The proposed research hypothesis is tested both empirically and statistically by conducting computational experiments and performance analysis, following a systematic procedure, as presented in Figure 1.

Computational Experiments

To test the proposed hypotheses on the nine variants of GHM-ATC for DS-SBO, we need to have suitable benchmark procedure for comparing with the proposed GHM for DS-SBO, experimental design for generating suitable test data, and performance measure for empirically and statistically measuring the impact of job and resource related real time events on the proposed GHM for DS-SBO.

Benchmark Solution Procedure: In this paper, the estimated optimal solution procedure discussed in Rardin and Uzsoy (2001) is considered as benchmark solution procedure.

Experimental design: The purpose of experimental design is to generate suitable Data. Based on the problem defined in this study and the observation made in literature, five important problem parameters: number of jobs (N), release time of jobs (r_j), processing time of jobs (p_j), due-date of jobs (d_j), and size of jobs in terms of number of boards (W_j) required to place a customer's order are considered for the study. All the parameters' value except number of jobs is drawn appropriately defining uniform distributions. Accordingly, an experimental design is developed and presented in Table 2.

Performance Measure: The standard performance measures: *Average Relative Percentage Deviation (ARPD)* and *Maximum Relative Percentage Deviation (MRPD)* are considered. For computing ARPD, the relative percentage deviation (RPD) with respect to estimated optimal solution (EOS) is computed using equation (1) for each of the problem instances. Further, the average of RPD (ARPD) over the number of problem instances planned in each of the problem configurations is computed using equation (2) for each of the problem configurations (that is 10 instances) and for overall problem instances (that is 640 instances). The performance measure: ARPD provides the average performance of the GHM-ATC.

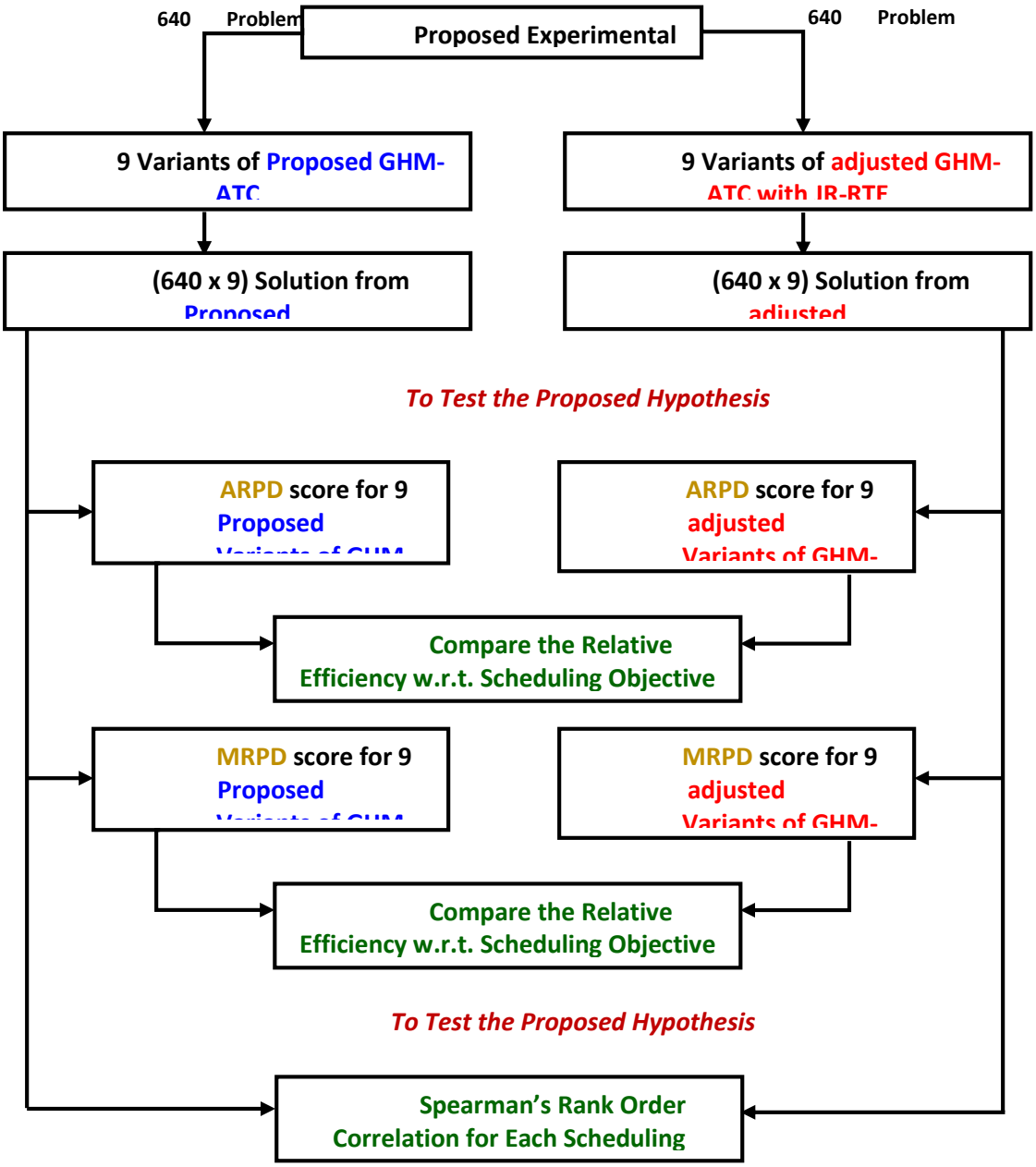

Figure 1: A systematic research process carried out for testing the proposed research hypothesis

Table 2: A summary of the proposed experimental design

Problem Parameters	**Number of Levels**	**Level wise Values**
Number of Jobs (N)	4	10, 20, 50, 100
Job Release time (r_j)	2	[1,20], [1,30]
Job Processing Time (p_j)	2	[1,10], [1,15]
Job Due-date (d_j)	2	{r_j + p_j + [1,30]}, {r_j + p_j + [1,45]}
Job Size (W_j)	2	[4,10], [4,14]
Number of Problem Configurations	4 x 2 x 2 x 2x 2 = 64	
Number of Instances per Configurations	10	
Total Number of Instances	64 x 10 = 640	

The maximum of RPD (MRPD) over the number of problem instances planned in each of the problem configurations is computed using the equation (3) for each of the problem configurations and for overall problem instances. The performance measure: MRPD provides the worst case performance of the GHM-ATC.

$$RPD = [(SOV(GHM) - EOS)/EOS] * 100 \quad (1)$$

Where

SOV(GHM) – Scheduling Objective (example: TWT/TWCT/Cmax) Value obtained from 'GHM' for a problem instance

EOS – Estimated Optimal Solution for the corresponding problem instance

$$ARPD = \sum_{i=1}^{N} RPD/N \quad (2)$$

Where

N = 10 when ARPD is computed problem configuration wise, and

N = 640 when ARPD is computed considering entire problem instances

$$MRPD = \max_{i=1,2,\ldots N} \left(RPD_{ij}\right) \quad (3)$$

Where

N = 10 when MRPD is computed problem configuration wise, and

N = 640 when ARPD is computed considering entire problem instances

Performance Analysis

All these nine variants of the GHM-ATC for DS-SBO are implemented using Turbo C with k value set to 0.5 (Li *et al.* (2010)). In each of the implemented variant of GHM-ATC, the real time event related to job such as rush job, due-date change, early/late arrival of job, change in job priority, job cancellation and/or resource such as machine breakdown, operator illness, tool failure, shortage of material, and defective material is randomly triggered with equal occurrences before forming a batch and deciding to schedule in burn-in oven by suitably introducing additional code. Depending upon the occurrence of RTE, either work-in process data or the data on the next available time of the burn-in oven is adjusted appropriately before forming a batch and deciding a schedule in the burn-in oven. This version of the variants of GHM-ATC is called as adjusted GHM-ATC with JR-RTE.

Before understanding the impact of the occurrences of JR-RTE on the relative efficiency of the nine proposed variants of GHM-ATC for DS-SBO, problem configuration wise, the total number of JR-RTE occurred in each of the nine adjusted variants of GHM-ATC with JR-RTE for DS-SBO is computed, by solving each of the 640 problem instances using each of the adjusted variants of GHM-ATC, and presented in Table 3. From this table, it is observed that, on an average ten real time events related to either job or resource are triggered randomly in each of the problem instances and in each of the nine adjusted variants of GHM-ATC with JR-RTE.

Further, for each of the nine adjusted variants of GHM-ATC with JR-RTE, minimum, average, and maximum number of occurrences JR-RTE over 640 problem instances is computed. Due to brevity of the study, these details related to adjusted variant 1 is presented in Table 4 along with the corresponding job size and completion time. From this table, it is observed that, out of 640 problem instances, the occurrences of JR-RTE is between a minimum of 1 to a maximum of 12 within a span of 1 and 15 days respectively. Further, on an average 10 JR-RTE occurred in 7 days.

Table 3: Number of occurrence of JR-RTE in each of the nine adjusted variant of GHM-ATC

Problem Configuration	**No. of Jobs**	**Number of occurrence of JR-RTE in adjusted variant**								
		1	2	3	4	5	6	7	8	9
1	10	22	23	22	23	24	25	25	22	22
2	10	34	36	35	34	33	35	33	35	34
3	10	27	27	28	28	27	28	28	27	27
4	10	36	36	35	36	36	35	35	35	35
5	10	27	26	28	25	26	28	28	28	28
6	10	37	35	35	36	37	36	37	35	35
7	10	25	26	26	26	27	26	26	26	26
8	10	36	34	34	34	33	33	34	35	35
9	10	25	26	26	27	27	27	27	25	25
10	10	38	37	36	38	38	35	36	36	37
11	10	25	25	25	25	25	25	25	25	25
12	10	33	33	34	36	36	34	33	36	36
13	10	25	26	24	23	25	25	25	25	26
14	10	36	35	35	34	33	35	34	35	35
15	10	27	26	27	26	26	26	28	27	26
16	10	37	37	39	36	38	38	38	37	35
17	20	59	61	59	56	57	58	59	60	57
18	20	69	69	70	71	70	68	68	69	68
19	20	58	59	57	55	57	59	60	59	58
20	20	72	72	72	71	71	72	70	70	70
21	20	60	62	60	60	62	61	63	60	62
22	20	69	69	69	70	68	70	66	69	68
23	20	55	57	57	58	57	57	57	56	57
24	20	71	73	70	71	71	70	71	71	71
25	20	57	59	55	56	56	58	55	55	56
26	20	71	71	70	71	70	71	73	71	70
27	20	58	59	57	58	57	58	58	58	57
28	20	71	71	71	71	71	70	70	70	71
29	20	56	56	56	58	58	57	59	56	56
30	20	70	70	69	70	70	70	71	70	70
31	20	57	58	59	58	58	60	59	60	59
32	20	71	72	71	71	72	72	72	71	70
33	50	107	106	107	106	108	106	107	110	108

Table 3: Number of occurrence of JR-RTE in each of the nine adjusted variant of GHM-ATC - Cont...

Problem Configuration	**No. of Jobs**	**Number of occurrence of JR-RTE in adjusted variant**								
		1	2	3	4	5	6	7	8	9
34	50	128	132	129	127	129	134	134	130	127
35	50	106	103	106	104	105	105	103	103	105
36	50	129	126	129	124	128	130	128	126	129
37	50	107	107	107	106	107	107	106	108	106
38	50	129	128	126	129	130	130	129	129	127
39	50	103	104	103	104	103	103	103	104	105
40	50	127	131	128	129	125	130	128	134	130
41	50	107	106	106	107	105	105	106	106	106
42	50	128	129	131	120	127	129	126	131	130
43	50	102	104	103	103	105	103	103	105	105
44	50	127	129	129	124	126	127	125	128	132
45	50	105	104	104	106	105	104	107	105	105
46	50	128	125	125	132	125	127	129	123	127
47	50	106	105	105	105	106	104	106	105	106
48	50	129	131	131	129	131	130	133	130	129
49	100	182	180	180	180	180	184	180	183	180
50	100	245	245	242	243	246	248	248	244	248
51	100	181	181	182	181	180	181	181	180	183
52	100	248	249	248	249	246	246	250	249	249
53	100	186	185	185	181	181	185	185	183	185
54	100	252	252	253	250	248	253	245	251	249
55	100	183	181	181	182	181	181	183	182	181
56	100	250	255	248	249	246	255	246	254	246
57	100	183	181	181	181	183	181	182	182	185
58	100	250	249	245	246	244	249	246	245	245
59	100	181	180	183	181	183	184	181	180	183
60	100	245	246	245	243	241	246	243	246	246
61	100	182	184	183	184	180	183	182	184	183
62	100	241	243	246	245	241	244	247	246	247
63	100	182	180	181	181	180	183	180	180	182
64	100	241	241	242	236	238	241	236	239	238
Average no. of occurrences of JR-RTE per configuration		104.3	104.6	104.2	103.9	103.8	104.7	104.4	104.4	104.4
Average no. of occurrences of JR-RTE per instances		10	10	10	10	10	10	10	10	10

Table 4: Number of occurrences of JR-RTE in adjusted variant 1 of GHM-ATC over 640 Instances

Out of 640 problem instances	**No. of occurrences of**			**No. of jobs**	**Completion time (in Days)**
	J-RTE	**R-RTE**	**Total**		
Minimum	1	1	2	10	1
Average	6	4	10	45	7
Maximum	12	16	28	100	15

For understanding the impact of JR-RTE on each of the nine GHM-ATC for DS-SBO, each of the 640 problem instances are solved using each of the nine variants of (a) GHM-ATC, and (b) adjusted GHM-ATC with JR-RTE. This process result two sets of nine feasible solutions, for each of the problem instances related to scheduling of SBO considering (i) only future arrival of jobs, and (ii) future arrival of jobs and JR-RTE, with respect to each of the scheduling objectives: TWT, TWCT, and Cmax respectively. With respect to each of the scheduling objective, using each set of nine feasible solutions obtained for each of the problem instances, an estimated optimal solution is obtained as discussed in Rardin and Uzsoy (2001).

With respect to each of the scheduling objectives, problem configuration wise ARPD and MRPD in comparison with estimated optimal solution is computed as per equation (2) and (3) respectively for each of the nine variants of (a) GHM-ATC, and (b) adjusted GHM-ATC with RTE and the same is presented in Annexure 1 to Annexure 6 respectively. Further, irrespective of problem configuration, ARPD and MRPD score over 640 problem instances are computed using equation (2) and (3) respectively for each of the nine variants of (a) GHM-ATC, and (b) adjusted GHM-ATC with JR-RTE for each of the scheduling objectives considered in this study and is presented in Figure 2 and Figure 3 respectively.

Testing of the proposed hypothesis based on ARPD score obtained over 640 problem instances (Figure 2), empirically says that, there is no significant difference on the relative efficiency between each of the nine proposed variants of GHM-ATC, and the corresponding adjusted GHM-ATC with JR-RTE for DS-SBO while minimizing the scheduling objectives: TWT, TWCT, and Cmax.

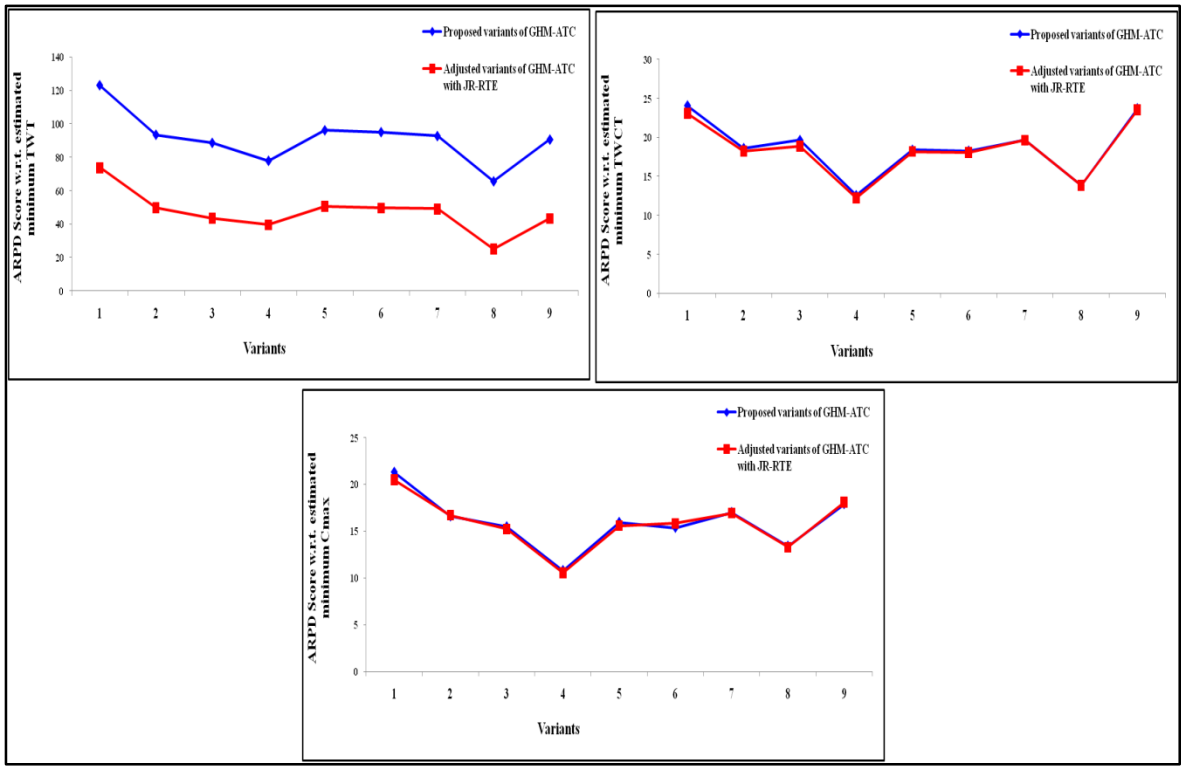

Figure 2: Relative efficiency of nine **proposed variants of GHM-ATC** and **adjusted variants of GHM-ATC with JR-RTE** based on **ARPD score** while minimizing TWT, TWCT, and Cmax

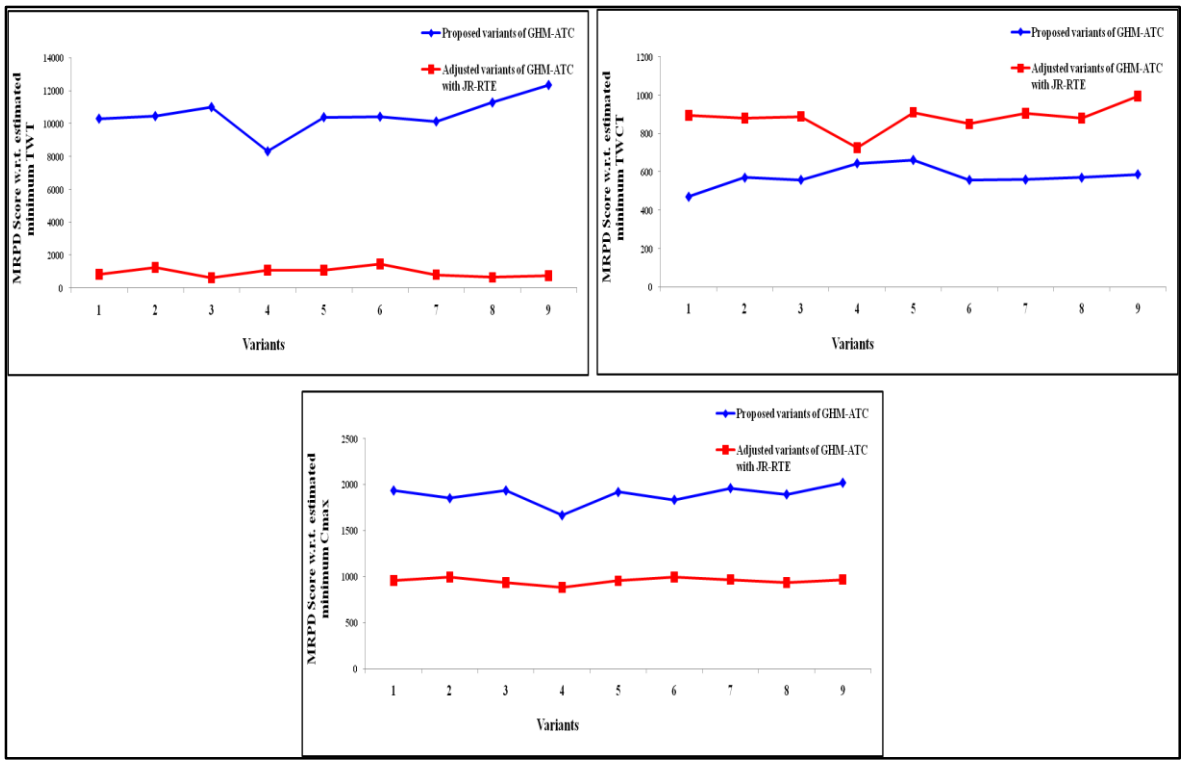

Figure 3: Relative efficiency of nine **proposed variants of GHM-ATC** and **adjusted variants of GHM-ATC with JR-RTE** based on **MRPD score** while minimizing TWT, TWCT, and Cmax

However, with respect to MRPD score obtained over 640 problem instances, there is some difference in the relative efficiency between proposed variants of GHM-ATC and the corresponding adjusted GHM-ATC with JR-RTE for DS-SBO (Refer, Figure 3). Hence, this study further verify whether these differences are statistically significant or not by testing the proposed hypotheses statistically by conducting Spearman's rank order correlation between each of the nine variants of GHM-ATC and the corresponding adjusted GHM-ATC with JR-RTE for each of the scheduling objectives considered in this study and the results obtained related to P-value and correlation coefficients are presented in Table 5.

From Table 5, it is observed that P-value of all the nine variants with respect to each of the single objectives are **strictly less than 0.05.** Hence, statistically there is a strong evidence to reject the null hypothesis defined in this study related to each of the scheduling objectives: TWT, TWCT, and Cmax (that is, $H1_0$ to $H3_0$). Thus, there is no significant difference on the relative efficiency between each of the nine proposed variants of GHM-ATC, and the corresponding adjusted GHM-ATC with JR-RTE for DS-SBO while minimizing each of the scheduling objectives: TWT, TWCT, & Cmax. Further, correlation coefficient between each of the nine proposed variants of GHM-ATC, and the corresponding adjusted GHM-ATC with JR-RTE are close to one, which indicates, these two cases [that is, proposed GHM-ATC and adjusted GHM-ATC with JR-RTE] are highly correlated positively. Hence, the variants, which are efficient in proposed GHM-ATC, are also efficient in adjusted GHM-ATC with JR-RTE.

From the empirical and statistical analysis, this study concludes that, "*there is no significant difference on the relative efficiency between each of the nine proposed variants of GHM-ATC, and the corresponding adjusted GHM-ATC with JR-RTE for DS-SBO while minimizing the scheduling objectives: TWT, TWCT, and Cmax*". Hence, there is no impact of JR-RTE on the relative efficiency of the nine proposed variants of GHM-ATC, and the corresponding adjusted GHM-ATC with JR-RTE while minimizing the scheduling objectives considered in this study for DS-SBO.

Table 5: Statistical significance of the nine variants of GHM-ATC and adjusted GHM-ATC with JR-RTE w.r.t. various scheduling objectives

Variants	Correlation Significance Test P-Value	Correlation coefficient of each of the nine variants of GHM-ATC and adjusted GHM-ATC with JR-RTE for the scheduling objectives		
		TWT	TWCT	Cmax
1	<2.2e-16	0.9992351	0.9997077	0.9983149
2	<2.2e-16	0.9986105	0.9995992	0.9972636
3	<2.2e-16	0.9986099	0.9995022	0.9973187
4	<2.2e-16	0.9976637	0.9992972	0.9962523
5	<2.2e-16	0.9982405	0.9993675	0.9971928
6	<2.2e-16	0.9978339	0.9994035	0.9968652
7	<2.2e-16	0.9978709	0.9993131	0.997349
8	<2.2e-16	0.998423	0.9995106	0.9977331
9	<2.2e-16	0.9979977	0.9992247	0.9970962

Thus, if any JR-RTE occurs then modifying appropriately the work-in-process (WIP) data and/or the availability time of the burn-in oven depending upon the occurrence of job and/or resource related real time events respectively by utilizing the existing computerized tracking system in the shop floor is sufficient when there is an efficient algorithm for dynamic scheduling of burn-in oven considering only future arrival of jobs and no need to modify the algorithm.

CONCLUSION

The analysis of the literature indicated that there is no algorithm in scheduling of burn-in oven considering together the problem characteristics on future arrival of jobs and the occurrence of job and or resource related real time events along with the other problem characteristics such as jobs having different (a) processing time requirements, (b) sizes, (c) release times, (d) due-dates, and (e) the non-agreeable release times and due dates with respect to any scheduling objectives. It is observed in the literature that there are studies in scheduling discrete processor considering together the problem characteristics on future arrival of jobs and the occurrence of job and or resource related real time events. In this case the researchers suggested that either existing

algorithm has to be changed or re-scheduling algorithm needs to be proposed whenever real time event occurs.

However, this study proposed hypothesis that if there is any efficient algorithm(s) for dynamic scheduling of burn-in oven (that is scheduling burn-in oven considering future arrival of jobs only) then changing appropriately the work-in process data or the data on the availability time of burn-in oven for next scheduling depending upon the occurrence of job related real time event or resource related event respectively is sufficient.

The proposed research hypothesis was proved both empirically and statistically considering nine variants of Greed Heuristic Method based on Apparent Tardiness Cost (GHM-ATC) for Dynamic Scheduling of Single Burn-in Oven (DS-SBO) along with the experimental design available in the literature by conducting a detailed computational experiments and performances analysis with respect to each of the scheduling objectives: TWT, TWCT, and Cmax considered in this study. At the end of the computational analysis, the proposed hypothesis has become true and this is probably due to (a) the lengthiest processing time requirement for burn-in operation, (b) the existence of computerised shop floor system for tracking and controlling, and (c) very meagre computational time requirement for the efficient algorithm: GHM-ATC, considered for DS-SBO. That is, before constructing a batch and deciding to schedule a batch at a particular decision making time epoch, it is possible to change the data related to the occurrence of any real time events as the computerized system provides all the right and relevant information about the job and resources and there is huge time difference is existing between the expected completion time of the burn-in oven and the decision making time epoch for constructing a batch and deciding to go for next schedule of a batch .

This study has considered a single burn-in oven and studied the impact of real time events on the efficient algorithm in DS-SBO. In reality there will be multiple burn-in ovens available in parallel with different capacity and the inferences obtained in this study with respect to single burn-in oven needs to be studied on dynamic scheduling of multiple non-identical burn-in ovens. This is our immediate extension to the research problem considered in this study.

Annexure 1

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal TWT** based on **ARPD score**

Problem configuration	ARPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal TWT									ARPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal TWT								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	132.83	88.22	74.17	83.52	87.71	71.56	60.78	30.98	38.69	93.64	53.17	48.76	65.00	66.09	48.69	45.24	10.81	20.16
2	97.20	56.87	43.02	159.20	157.90	141.62	175.00	4.78	17.70	97.00	130.88	80.64	172.37	170.99	182.65	188.81	61.26	68.49
3	99.84	153.91	161.53	39.68	159.99	279.17	40.10	135.08	138.24	197.95	105.98	106.31	57.52	129.74	224.38	59.57	90.78	92.94
4	119.30	193.75	47.67	84.15	86.46	60.74	59.78	36.49	53.20	185.15	205.03	80.71	234.54	233.25	150.84	151.02	13.18	29.03
5	89.34	48.40	48.25	42.84	71.56	58.23	63.23	26.02	48.96	84.99	46.12	44.18	40.91	65.44	56.05	59.15	25.74	44.83
6	101.68	111.72	127.68	165.02	169.58	179.84	150.68	104.44	114.37	34.36	22.21	21.34	65.52	73.66	44.27	30.89	14.24	18.96
7	347.10	207.40	26.94	292.85	313.69	200.89	179.59	10.83	10.83	163.12	112.14	21.80	135.71	137.83	115.35	102.83	11.54	11.54
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29	156.57	46.83	109.66	50.50	60.30	58.89	58.76	40.03	63.16	123.09	31.97	71.81	35.71	40.05	43.21	33.82	28.94	40.00
30	42.76	16.18	40.53	9.49	23.06	22.00	25.69	17.09	41.72	33.78	19.25	33.56	9.00	22.73	19.45	24.79	14.23	35.82
31	50.60	44.77	60.65	32.35	23.30	38.85	39.19	11.03	32.03	35.80	39.93	50.08	19.60	19.52	33.63	19.62	11.00	31.63
32	54.37	29.90	31.11	20.92	22.85	28.76	24.54	11.56	20.09	55.45	33.31	28.51	20.80	25.32	30.70	22.86	13.48	21.57
33	43.50	25.12	39.16	6.95	21.82	22.98	27.78	22.16	49.13	44.21	23.98	34.56	9.78	21.77	23.92	27.82	23.15	44.52
34	40.64	27.58	37.77	6.54	17.84	26.54	30.13	24.85	41.10	-46.70	-53.88	-51.48	-55.57	-53.48	-56.74	-49.06	-52.47	-40.62
35	33.92	20.30	35.12	3.51	18.83	16.94	21.78	14.39	47.47	27.86	17.06	28.49	6.90	19.74	17.73	19.63	15.22	42.14
.																		
.																		
58	63.02	50.29	56.42	26.40	45.73	48.65	54.50	46.88	75.10	55.04	47.06	46.28	24.28	42.82	44.39	49.65	42.84	66.78
59	41.67	28.51	42.99	11.13	38.34	27.86	37.69	26.55	70.52	62.71	53.15	65.89	31.07	64.58	55.07	70.47	51.07	93.51
60	36.29	26.68	31.94	7.44	28.12	25.89	32.93	23.86	53.20	19.53	15.62	17.57	-1.22	16.03	15.59	20.15	9.54	36.31
61	65.82	57.21	63.22	30.95	61.86	55.79	63.50	52.46	92.84	46.37	36.99	43.94	16.91	40.04	36.72	44.52	34.40	69.24
62	45.89	36.52	39.73	16.48	36.86	36.83	39.78	37.33	64.36	48.45	41.88	49.99	26.00	42.86	42.84	49.77	43.93	71.10
63	46.38	37.98	46.22	17.55	48.58	36.64	53.01	38.48	76.42	60.50	50.21	58.86	28.30	59.18	48.43	62.32	50.90	87.45
64	22.12	15.04	17.36	0.80	24.15	12.15	16.75	15.58	33.95	37.19	27.80	30.25	9.54	36.19	27.74	31.21	26.14	48.83

Due to the brevity of the paper only samples are given

Annexure 2

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal TWCT** based on **ARPD score**

Problem configuration	ARPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal TWCT									ARPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal TWCT								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	10.52	8.84	4.60	9.68	10.71	8.94	8.64	0.97	1.75	9.98	8.65	4.60	8.40	9.59	7.86	7.62	1.20	2.40
2	10.88	11.71	8.51	19.43	19.09	17.75	20.07	3.86	6.04	11.84	16.10	11.43	20.60	20.10	21.21	22.19	8.43	9.57
3	9.61	9.53	-0.60	8.27	10.46	10.93	8.51	1.59	1.83	9.54	9.83	-0.43	8.71	10.46	11.29	9.12	1.67	1.90
4	-1.80	7.57	-1.23	6.65	6.48	4.79	4.13	-2.98	-1.73	-1.23	7.10	-0.63	7.15	6.76	4.38	4.44	-3.17	-1.77
5	26.66	17.20	13.79	16.23	22.28	20.29	20.44	11.22	14.53	27.29	17.72	14.44	17.34	22.66	21.39	20.98	12.05	15.32
6	35.13	29.99	26.67	38.82	38.32	40.12	32.85	28.63	31.72	9.35	7.93	8.55	16.68	19.56	14.73	12.58	6.28	7.90
7	14.74	17.95	3.44	14.36	17.80	14.22	12.84	2.89	2.89	13.64	17.20	3.84	16.31	16.87	15.93	14.68	3.30	3.30
.																		
.																		
29	31.97	11.06	20.52	9.54	11.61	11.01	10.55	6.61	11.77	43.17	20.65	30.02	21.83	22.69	24.67	22.65	17.26	22.61
30	12.87	5.23	13.26	3.37	8.61	7.23	9.17	5.53	14.48	11.05	6.33	12.81	2.90	8.92	7.59	9.59	4.99	14.10
31	11.10	11.74	15.30	7.01	5.79	8.79	9.41	3.64	9.00	10.43	12.90	15.03	6.39	6.46	9.23	6.74	3.89	10.60
32	16.64	11.16	9.62	8.54	8.96	11.01	9.55	4.58	7.48	17.94	12.91	9.52	8.55	10.08	11.54	8.90	5.20	8.17
33	21.25	12.59	19.91	3.28	11.02	11.27	14.13	10.92	25.23	31.49	20.63	26.72	11.45	18.51	20.34	22.62	20.30	32.94
34	22.54	16.04	21.83	4.21	10.81	15.48	17.62	14.30	23.76	7.97	6.29	6.31	-3.67	2.84	4.56	7.16	3.69	16.05
35	11.49	8.18	14.15	1.54	7.87	7.16	9.18	6.00	19.82	11.26	7.84	13.41	3.13	8.66	8.21	9.49	6.68	19.65
.																		
.																		
58	34.61	27.51	31.36	13.42	25.04	27.00	30.18	25.13	43.14	31.86	26.78	26.14	12.39	23.71	25.23	28.33	23.78	39.01
59	18.70	13.54	20.59	5.21	18.47	13.24	18.21	12.57	34.12	20.04	16.60	23.11	7.76	22.62	17.78	24.49	16.03	37.18
60	28.48	24.55	29.11	12.71	25.55	24.10	28.78	23.04	40.62	80.38	77.45	80.03	60.97	78.74	79.01	86.76	75.97	97.81
61	34.81	30.53	34.12	15.85	33.48	29.64	34.47	27.94	51.47	28.45	22.84	27.49	10.05	24.58	22.40	27.82	21.27	44.17
62	31.12	25.10	27.42	11.22	25.44	25.33	27.49	25.67	44.76	27.04	22.65	28.58	12.71	24.05	23.33	28.28	24.47	43.19
63	24.59	21.05	25.89	9.50	27.34	20.22	29.75	21.29	43.32	29.79	25.07	29.58	13.19	29.96	24.04	31.86	25.42	46.73
64	9.43	5.61	7.21	-3.80	11.78	3.59	6.64	5.91	18.18	56.40	48.05	52.27	30.17	54.09	48.37	51.01	46.91	68.61

Annexure 3

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal Cmax** based on **ARPD score**

Problem configuration	ARPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal Cmax									ARPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal Cmax								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	16.93	12.40	8.55	12.00	14.35	12.82	12.76	4.90	5.55	16.73	13.11	7.34	11.52	15.41	15.93	15.84	3.40	3.82
2	9.58	4.68	4.84	6.58	6.88	4.95	7.37	2.82	2.78	11.23	9.32	6.17	9.09	5.93	10.00	7.74	4.51	3.31
3	8.91	7.14	2.93	7.08	7.36	7.99	6.85	3.06	3.06	9.50	6.43	3.57	7.44	6.63	8.32	7.24	2.66	2.66
4	9.78	15.40	2.50	11.53	11.59	10.74	11.18	2.90	3.93	7.54	13.07	3.80	8.72	9.27	10.02	8.59	1.24	3.73
5	20.75	10.54	11.30	5.60	10.35	13.71	13.21	9.27	8.92	15.02	5.60	7.58	-0.72	5.17	9.48	9.18	5.75	5.51
6	16.33	10.73	6.42	9.14	12.23	10.94	15.42	8.95	9.63	12.88	8.62	6.87	7.48	13.09	8.54	13.66	6.38	7.12
7	16.84	15.02	2.23	10.10	16.37	11.20	10.77	1.72	1.72	14.75	14.06	2.51	13.15	16.48	14.02	13.54	2.00	2.00
.																		
.																		
29	31.31	14.59	19.46	13.26	14.76	15.52	17.84	14.25	14.32	24.04	7.16	13.22	10.25	10.57	10.23	12.10	5.80	9.02
30	18.23	10.26	11.24	5.64	12.35	7.90	13.32	11.43	14.78	26.18	22.32	23.23	15.15	23.87	22.18	25.34	20.76	24.66
31	4.95	4.01	6.89	1.72	0.36	2.46	2.67	0.19	3.67	16.98	19.72	21.95	12.39	15.22	18.39	14.42	14.42	19.17
32	20.28	15.93	11.30	9.53	12.53	14.12	11.51	6.59	9.10	18.93	16.44	10.11	8.81	10.50	14.09	12.20	6.47	7.59
33	31.54	27.30	28.83	15.74	25.26	24.32	27.32	25.14	34.54	18.82	11.82	13.60	4.36	12.48	13.01	13.79	13.95	20.13
34	16.13	12.86	11.97	2.66	9.56	12.42	13.19	11.62	13.68	31.18	30.02	26.65	19.84	25.47	27.70	27.05	27.39	33.78
35	17.69	11.42	13.37	5.65	11.58	10.92	13.15	11.44	18.99	12.14	7.87	10.92	2.32	7.51	10.43	9.26	5.99	15.09
.																		
.																		
58	27.76	23.27	24.79	15.81	25.14	23.97	26.01	21.69	29.65	32.46	29.86	27.58	18.64	27.25	28.95	29.29	27.54	33.19
59	18.99	14.50	17.38	7.27	19.30	14.81	18.26	14.30	27.58	31.35	27.39	28.57	15.85	33.47	26.91	35.19	26.08	37.85
60	73.75	71.16	69.34	54.60	76.57	71.04	72.33	69.81	82.69	92.79	94.83	88.96	77.42	90.62	94.89	92.89	87.01	96.30
61	10.51	8.83	8.58	0.37	11.29	8.51	10.94	7.06	16.98	23.22	20.02	20.04	9.29	20.06	19.24	22.75	18.72	31.05
62	6.03	3.51	3.21	-4.73	4.31	3.83	4.20	4.29	10.76	9.30	8.40	12.71	2.00	10.51	9.08	12.79	9.51	17.45
63	4.23	3.04	3.66	-5.23	7.53	2.07	7.49	3.83	12.04	16.71	13.33	13.05	5.07	17.15	12.43	17.08	13.96	23.92
64	-0.54	-2.26	-2.49	-9.61	2.56	-3.53	-1.45	-1.71	1.67	-21.62	-23.05	-22.85	-30.53	-20.40	-23.41	-23.12	-24.40	-20.25

Annexure 4

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal TWT** based on **MRPD score**

Problem configuration	MRPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal TWT									MRPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal TWT								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	433.33	390.24	297.56	550.79	550.79	350.79	350.79	297.56	297.56	369.33	290.67	181.33	458.67	458.67	301.33	301.33	71.70	109.84
2	300.00	209.09	207.77	977.50	977.50	790.00	977.50	25.80	76.69	237.15	737.83	448.49	677.45	677.45	737.83	737.83	418.30	418.30
3	300.00	962.50	628.57	144.16	962.50	1912.50	144.16	962.50	962.50	845.45	650.00	483.33	181.82	650.00	1483.33	181.82	650.00	650.00
4	485.81	905.13	152.99	251.14	251.14	215.91	215.91	248.67	299.94	850.00	1253.85	350.00	1085.71	1085.71	571.43	571.43	118.58	209.88
5	155.93	145.88	250.04	113.12	144.01	113.12	144.01	120.06	266.17	150.00	136.86	208.62	138.44	138.44	138.44	138.44	109.74	223.60
6	661.60	888.89	1072.22	1002.53	1027.64	1096.71	1160.75	888.89	876.33	80.82	55.64	54.92	268.36	313.91	209.35	114.68	54.08	54.08
7	1293.33	1250.00	100.00	1420.00	1420.00	1350.00	1250.00	84.62	84.62	493.33	442.86	63.27	442.86	442.86	465.31	442.86	58.89	58.89
.																		
.																		
29	517.60	104.46	473.47	226.21	233.66	269.81	262.64	270.35	307.57	292.34	74.42	258.58	139.84	144.97	134.26	117.67	165.82	147.18
30	111.90	59.64	110.46	40.12	48.44	72.32	60.37	62.12	114.31	94.19	74.10	73.63	35.27	53.38	59.21	53.85	51.59	89.40
31	98.18	127.26	109.60	149.81	140.36	157.91	140.81	44.29	79.77	103.30	102.14	72.84	97.77	122.78	133.63	122.01	34.82	61.98
32	148.65	60.64	99.37	76.59	90.80	60.64	63.74	39.41	40.79	160.09	57.46	59.40	44.84	52.63	57.46	59.01	48.10	49.61
33	104.96	72.35	100.53	43.30	67.41	84.77	81.37	76.46	92.26	112.94	79.40	101.74	55.81	83.57	81.74	86.69	84.18	112.51
34	59.58	40.21	50.01	15.06	26.44	40.49	43.43	42.81	69.60	97.66	72.12	80.13	47.32	73.01	68.17	88.50	72.12	98.20
35	70.96	57.02	66.68	11.33	44.84	34.82	43.80	29.06	62.09	62.23	49.11	72.08	25.25	58.12	49.11	51.00	49.11	98.94
.																		
.																		
58	302.06	268.31	279.38	186.46	239.67	246.31	270.34	276.81	308.06	150.05	126.55	129.64	88.88	124.05	126.55	138.82	119.91	161.79
59	93.56	76.52	95.01	40.60	70.52	71.77	71.61	72.90	122.49	334.69	303.95	301.43	212.00	308.63	296.67	357.70	275.38	354.00
60	127.83	93.80	98.36	64.11	106.17	91.66	108.31	90.52	127.34	34.21	39.76	33.55	14.48	36.11	39.76	39.22	27.88	61.23
61	232.49	225.05	232.62	144.71	221.18	222.05	229.85	205.41	291.59	165.40	151.68	152.04	93.14	152.34	133.55	153.09	129.06	178.84
62	89.35	75.46	67.90	49.15	76.05	75.21	85.51	77.13	93.79	191.99	179.84	185.78	141.67	175.06	179.84	189.86	179.84	216.33
63	96.94	86.19	95.49	45.72	91.70	84.14	99.52	84.62	139.26	122.30	114.99	130.31	80.64	138.13	110.28	141.33	116.47	160.21
64	87.39	72.04	77.18	47.60	90.99	70.60	79.74	71.52	104.71	150.16	129.62	140.23	91.57	147.57	129.27	126.62	125.38	171.68

Annexure 5

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal TWCT** based on **MRPD score**

Problem configuration	MRPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal TWCT									MRPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal TWCT								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	60.91	24.58	17.46	37.24	37.24	25.16	25.16	9.14	17.46	55.95	24.73	17.22	36.70	36.70	25.31	25.31	9.07	17.22
2	26.09	33.96	23.06	57.33	57.33	51.42	57.33	14.67	16.21	23.98	57.64	33.01	55.66	55.66	57.64	57.64	30.95	30.95
3	44.14	45.48	13.92	45.48	45.48	45.48	45.48	25.71	25.71	43.63	45.03	11.91	45.03	45.03	45.03	45.03	28.82	28.82
4	12.94	54.29	14.74	25.65	25.65	22.84	22.84	3.17	7.94	14.13	49.26	11.39	24.33	24.33	21.82	21.82	2.41	6.32
5	62.33	62.33	43.71	84.86	93.86	84.86	93.86	63.19	63.19	66.68	66.68	45.64	97.31	97.31	97.31	97.31	65.67	65.67
6	335.35	290.94	252.41	317.35	292.38	303.42	290.94	290.94	290.94	19.76	24.92	25.21	56.65	66.58	44.06	46.64	24.92	24.92
7	30.26	49.45	22.66	36.69	36.69	52.40	51.65	23.46	23.46	28.63	49.63	22.88	35.38	35.38	52.28	51.49	23.62	23.62
.																		
.																		
29	49.01	24.03	43.44	33.92	33.92	31.33	31.33	25.05	27.94	115.82	108.12	110.40	122.18	122.18	123.73	123.93	94.32	110.93
30	35.89	16.12	28.88	10.56	19.60	20.77	23.57	16.29	43.70	36.72	18.63	23.03	11.40	22.32	15.29	21.93	15.32	37.22
31	29.60	28.66	36.39	26.73	25.25	29.17	29.32	18.96	28.31	28.52	26.71	28.18	22.78	27.79	29.97	27.64	16.62	25.11
32	30.37	26.55	22.81	18.20	21.47	22.56	23.37	13.29	14.58	38.49	22.92	21.60	14.67	25.06	19.94	20.79	17.43	17.97
33	46.10	32.52	44.46	19.85	30.25	37.69	36.35	33.96	40.89	134.55	111.94	128.36	92.73	112.30	113.17	117.42	116.11	135.12
34	33.85	22.38	26.97	12.07	16.41	25.32	28.59	23.06	37.25	31.34	21.98	23.43	9.25	28.90	21.98	27.27	19.16	32.74
35	28.64	20.62	23.50	4.97	16.40	12.55	16.22	12.66	24.05	23.91	19.70	30.53	9.57	23.58	19.70	21.46	19.70	42.48
.																		
.																		
58	141.52	126.16	131.63	87.04	112.48	115.72	127.17	130.30	145.34	107.01	93.74	94.97	70.54	92.22	93.74	101.48	90.17	115.26
59	41.28	35.17	43.37	19.07	32.57	33.11	33.02	33.43	55.61	58.16	52.18	49.46	29.10	51.55	49.45	65.33	43.60	63.41
60	137.38	134.14	152.09	112.97	136.13	134.23	144.28	133.94	158.82	580.86	572.85	575.39	512.99	574.53	586.59	631.59	586.99	639.70
61	96.83	95.02	98.32	60.87	93.43	93.69	97.02	86.62	123.27	94.17	86.85	87.04	54.78	86.03	75.54	87.06	74.79	102.11
62	62.81	53.07	47.91	34.81	53.55	52.92	60.14	54.30	65.94	81.00	74.96	78.21	56.97	73.34	74.96	79.98	74.96	94.41
63	47.21	46.74	50.17	23.73	45.53	45.62	51.95	45.86	75.63	61.08	63.24	71.84	45.22	75.65	61.16	77.32	63.86	82.51
64	51.06	42.70	46.03	27.56	54.56	41.70	47.55	42.25	63.10	333.45	305.82	329.83	244.01	313.90	305.82	311.99	303.61	377.76

Annexure 6

Performance analysis of each of the nine proposed variants of GHM-ATC and adjusted GHM-ATC with JR-RTE in comparison with **estimated optimal Cmax** based on **MRPD score**

Problem configuration	MRPD score of each of the proposed variants of GHM-ATC in comparison with estimated optimal Cmax									MRPD score of each of the adjusted variants of GHM-ATC with JR-RTE in comparison with estimated optimal Cmax								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	43.59	33.33	24.14	48.28	48.28	33.33	33.33	22.22	22.22	45.24	31.41	23.33	46.67	46.67	34.29	34.29	8.97	8.97
2	26.05	12.50	20.59	25.00	25.00	12.50	25.00	12.20	12.32	28.42	16.62	17.95	31.58	25.00	25.00	25.00	15.79	18.42
3	23.68	30.00	13.33	30.00	30.00	30.00	30.00	30.00	30.00	21.62	29.03	18.92	29.03	29.03	29.03	29.03	29.03	29.03
4	23.08	53.85	12.00	20.00	20.00	33.33	33.33	19.44	19.44	19.35	45.16	19.15	17.65	17.65	29.41	29.41	5.88	17.48
5	49.49	25.00	46.34	21.21	21.74	33.33	23.91	23.91	46.34	52.94	30.95	54.76	19.27	29.79	31.91	31.91	31.91	54.76
6	84.38	62.50	37.50	56.25	62.50	59.38	62.50	62.50	62.50	30.53	17.24	12.83	30.00	30.00	26.37	35.40	17.02	19.15
7	40.00	46.67	8.57	28.57	46.67	27.27	31.43	10.00	10.00	37.25	41.26	7.50	41.26	41.26	41.26	41.26	8.84	8.84
.																		
.																		
29	85.71	59.52	71.43	22.50	42.86	59.52	54.76	61.90	61.90	42.19	25.83	28.57	34.24	31.64	30.34	28.65	18.49	23.87
30	33.40	17.22	21.74	20.03	34.10	23.98	27.39	17.22	29.84	145.83	129.17	137.50	104.17	143.75	129.17	150.00	125.00	139.58
31	25.45	18.10	30.00	12.86	21.90	16.13	18.10	18.10	25.71	71.70	90.57	88.68	50.94	83.02	71.70	67.92	71.70	90.57
32	39.75	27.10	22.31	25.78	31.37	28.24	30.53	18.85	17.69	37.46	23.84	19.54	22.60	22.60	23.84	18.89	19.35	15.05
33	141.07	133.93	135.71	114.29	128.57	132.14	132.14	133.93	144.64	26.11	20.11	32.12	9.10	24.11	19.11	19.11	32.12	40.13
34	27.45	26.73	25.00	12.12	25.76	21.76	28.45	21.97	33.43	175.00	176.79	166.07	167.86	160.71	173.21	144.64	173.21	178.57
35	47.10	45.81	41.94	31.61	44.52	45.81	41.94	40.65	52.26	28.50	12.85	25.70	5.24	19.90	18.80	15.67	11.91	34.40
.																		
.																		
58	78.54	68.96	74.03	52.63	75.72	71.78	79.10	68.96	90.36	169.41	166.86	168.56	137.11	161.76	166.86	170.25	155.81	177.05
59	39.67	34.43	39.02	20.66	39.02	35.08	40.33	35.74	57.38	618.27	595.19	577.88	508.65	618.27	575.00	650.00	580.77	621.15
60	636.59	634.15	621.95	548.78	692.68	636.59	641.46	626.83	704.88	958.62	996.55	937.93	882.76	955.17	996.55	968.97	937.93	968.97
61	36.17	33.13	30.53	20.99	35.73	34.87	33.56	32.70	44.41	61.10	53.02	49.22	35.91	55.40	46.84	59.67	47.32	59.67
62	22.92	27.27	27.27	8.64	27.98	27.58	20.65	25.09	28.82	44.67	42.51	51.15	32.79	54.03	42.51	54.39	44.67	55.11
63	38.83	37.09	35.79	26.25	47.07	35.79	40.13	37.53	48.81	35.76	34.96	36.96	15.00	34.96	25.38	35.36	35.76	42.95
64	50.78	48.25	44.27	33.79	58.02	48.25	50.42	52.59	56.57	15.32	16.13	11.83	2.69	24.19	15.59	19.35	8.06	15.32

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SELECTION OF ON-SITE ENERGY GENERATION TECHNOLOGY WITH A NEW MCDM APPROACH USING MABAC & AHP

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ABSTRACT

Unlike centralized energy generation, distributed generation (DG) is located close to end-users to avoid transmission losses from long distance, supplies their energy needs with small-scale systems. With combined heat power systems, both the primary energy source utilization rate is significantly increased and the resulting gas emissions are also decreased in to same extent. There is wide range of DG options including renewable energy techniques. In this study, a new approach integrating a MCDM (Multi Criteria Decision Making) technique Multi-Attributive Border Approximation area Comparison (MABAC) with Analytic Hierarchy Process (AHP) is proposed to assess competitive benefits of DG technologies from economic, technic, environmental and social view. Based on ten different criteria, the best DG option is selected from five alternatives which are reciprocating engine (gas motor), micro turbine, fuel cell, solar photovoltaic system and wind turbine.

Keywords: Distributed generation, technology selection, MABAC, AHP, MCDM

1. Introduction

The efficient and effective use of primary energy resources is one of the most important problems to be solved today due to the intense environmental damage, global warming and climate change caused by the energy production process. Conventionally, energy is generated centrally, far away from end-users and this centralization causes large amounts of primary energy to waste as losses both during generation and transmission/distribution process. Due to greenhouse gas emissions during power generation in gigantic power plants, they have negative environmental impact as well.

Distributed generation, also called on-site generation, generates electricity energy at many small scale generation units located at or near the end-users. Combined Heat and Power (CHP), also known as cogeneration facilities, offers the possibility of generating heat and electricity simultaneously in an integrated system. This approach reduces the percentage of wasted primary

energy with very low energy transmission losses and the utilization of produced heat to cover local heating demands.

This distributed and combined approach provides numerous advantages over centralized and single generation. First, by locating generation units closer to the consumer, transmission and distribution losses are minimized. Second, CHP can reuse waste energy to generate thermal energy so it causes minimizing the primary energy consumption. Additionally, DG systems offer the opportunity to utilize from local renewable energy sources (e.g. solar, wind, biomass) and add flexibility [1].

International Energy Agency, predicts rapid growth for distributed electricity generation. It is estimated that the annual distribution of electricity will increase by 4.2% between 2000 and 2030 and reach 35 GW by 2030 [2].

Although, DG technologies are growing fast, there is wide range of DG alternatives. To achieve the maximum benefits of DG systems it is important to choose the right option according to our priority. The question we need to answer is which one is our priority; environmental friendship, reliability, lower cost, efficiency, continuity, or what? This problem is a multi-dimensional one. Decision-making methods can be used to assist researchers to evaluate available alternatives on different criteria.

Nigim et al. have used two MCDM (Multi Criteria Decision Making) methods for selecting local renewable energy sources. The first is the AHP (Analytic Hierarchy Process) method, which involves the collection of subject data and subject-matter expert opinions, and the second is the SIMUS (Sequential Interactive Model for Urban Sustainability) model that uses mathematical linear programming manipulation and contains more objective data. (SIMUS) [3].

Ren et al. have developed an integrated design and evaluation model to determine the optimal distributed energy system for residential use. They evaluated existing alternatives against economic, energetic and environmental criteria [4]. Zangeneh et al. have used AHP in their work to prioritize traditional and distributed production technologies to meet the growing energy need due to the growth rate in Iran. It has been concluded that the best alternative for Iran is gas turbines [5].

Nieto-Morote et al. [6] have used the Fuzzy Set Theory and AHP methods to evaluate economic, social, environmental and technical aspects in the selection of potential trigeneration systems for a residential building whereas Jing et al. [7] applied Gray Relational Analysis and

Combination Weighting methods for the same criteria and they have concluded that combined cycle is the best alternative, depending on its advanced technology. Streimikene and Balezentis [8] have used the TOPSIS method to evaluate small-scale cogeneration technologies based on economic, environmental and social criteria while Sanchez-Lozano et al. [9] have used a combination of AHP and TOPSIS methods for optimal placement of photovoltaic solar plants in Spain. Galgali et al. [10] ranked 5 alternatives among the distributed systems based on the expert opinion over the cost, noise, minimum start time, continuity and emission level criteria using the Fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) method. They obtained the preference ranking is PV, FC, RE, MT and WT.

In this study, we proposed a new approach by integrating the two MCDM techniques, AHP and MABAC (Multi-Attributive Border Approximation Area Comparison). Five DG technologies were evaluated based on 10 sub-criteria under heading economical, technical, environmental and social main criteria and the most appropriate alternative was selected on the basis of the priorities given to the criteria. Alternative technologies evaluated; reciprocating engines such a gas motor (RE), micro turbine (MT), fuel cell (FC), photovoltaic system (PV) and wind turbine (WT) (Fig. 1). Criteria weights were calculated by AHP method and then alternatives were sorted by MABAC method.

Fig. 1 Alternative technologies for distributed or on-site generation

2. Distributed Generation Technologies

2.1. Reciprocating Engines

There are two basic types of reciprocating or internal combustion engines: diesel engines and Otto-cycle engines, also known as gas engines. Reciprocating internal combustion engines are suitable for small-scale cogeneration applications because of their robust and well-proven technology however, they do need regular maintenance and servicing to ensure availability. They are available over a wide range of sizes making them suitable for numerous continuous cogeneration applications in residential or commercial. Depending on the engine size and type, high, medium and low speed engines can be used in cogeneration applications. Reciprocating engines have efficiencies that range from 25 to 45%. Achieving highest efficiency will result in conditions that produce about twice the gas emissions. The maintenance and high pollutant emission levels in case of diesel fueled engine are worrying areas.

2.2. Micro-turbine

Micro-turbine is small-scale version of gas turbine but its design is more complex than conventional simple cycle gas turbines. MT offers a number of advantages when compared to reciprocating based cogeneration systems. These include compact size, low weight, small number of moving parts and lower noise low maintenance requirements. MT capital cost is higher compared to the reciprocating engines while efficiency is less.

2.3. Fuel Cell

Fuel cell technology involves the reaction of hydrogen with oxygen in the presence of an electrolyte to produce electricity electrochemically without combustion and mechanical work. they have the potential to offer the highest efficiency of 85–90% for small-scale applications The advantages of fuel cell cogeneration systems include low noise level emissions, potential for low maintenance, modularity, compactness and contiunity. However, the high cost and relatively short lifetime of fuel cell systems are their main drawback. Solid Oxide Fuel Cells (SOFC) are suitable for residential cogeneration applications because they run efficiently at high temperatures, and have a favorable thermal/electric ratio.

2.4. Photovoltaic System

PV is a technology that transforms sunlight energy into electricity. This free energy source is found in abundance in a large part of the world. It generates DC current converted to AC using the power electronic circuit. The intermittent nature of the power can be overcome with the help of battery storage. PV systems range from small, roof-mounted systems with several tens of kilowatts to large scale power stations with hundreds of megawatts. Operating silently without any moving parts or environmental emissions, PV systems have become a fully-developed technology used for mainstream electricity generation where the cost per watt is steadily reducing.

2.5. Wind Turbine

The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. Due to the towers which are essential for mounting the turbines, installation cost becomes significant. There is zero emission. The noise level is not much, but it can cause danger to birds. Although not all the energy of blowing wind can be used, some small wind turbines are designed to work at low wind speeds. This is including on- or off-grid residences, telecom towers, rural schools and clinics, remote monitoring and other purposes that require energy where there is no electric grid, or where the grid is unstable. Small wind turbines may be as small as a fifty-watt generator [11].

3. Methodology

3.1. Analytical Hierarchical Process (AHP)

AHP is a relative measurement technique for qualitative and intangible criterion proposed by Saaty. It is a mathematical technique which develops a hierarchy of decision criteria and define the alternative courses of actions in decision making [12].

AHP algorithm is basically composed of two steps:

1. Determine the relative weights of the decision criteria
2. Determine the relative rankings (priorities) of alternatives.

A brief summary of AHP steps are as follows [13]:

Step 1: Firstly, set the goal which is followed by the selection of alternatives.

Step 2: Paired comparisons are needed in two segments such as follows:

(i) Among Criteria

(ii) Among Alternatives using each criterion.

Matrixes of pair-wise comparisons are created by the experts on the fundamental scale from 1 to 9. The comparison matrix is obtained as (n × n) where n denotes the number of criteria.

Step 3: Let X_{ij} denotes the order of preference of ith factor as compared to j^{th} factor. Then $X_{ji} = \frac{1}{X_{ij}}$

Step 4: A normalized pair-wise comparison matrix is obtained by adopting the following procedure:

a. Calculate the sum of every column.

b. Divide every member of the matrix respectively by its obtained column sum.

c. Take average of the rows to obtain relative weights.

Step 5: Calculate Eigen vector, maximum Eigen value (λ_{max}), n (number of criteria) and Consistency Index (CI) using Eq. (1).

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Step 6: Finally, Consistency Ratio (CR) is computed using Eq. (2).

$$CR = \frac{CI}{RI} \quad (2)$$

Where, RI stands for random index. The values of RI are depicted in Table 1.

Table 1. Possible values of RI [14]

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

In order for the matrix to be consistent, the CR must be smaller than 0.1.

3.2. Multi-Attributive Border Approximation area Comparison (MABAC)

After obtaining the weight coefficients, the conditions are ready to introduce the mathematical formulation of the MABAC method. The basis of the MABAC method is seen in the definition of the distance of the criterion function of each alternative from the border approximation area.

The MABAC method consists of 6 steps [15]:

Step 1. Formation of the initial decision matrix (X). The first step is to evaluate m alternatives according to n criteria. We show the alternatives in the form of vectors Ai = (x_{i1}, x_{i2}. . . x_{in}), where x_{ij} is the value of the ith alternative according to the jth criterion (i = 1, 2, . . ., m; j = 1, 2, . . ., n).

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \dots & \dots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \tag{3}$$

where m indicates the number of the alternatives, n indicates the total number of criteria.

Step 2. Normalization of the elements from the initial matrix (X).

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} n_{11} & n_{12} & \cdots & n_{1n} \\ n_{21} & n_{22} & \dots & n_{2n} \\ \vdots & \dots & \dots & \vdots \\ n_{m1} & n_{m2} & \cdots & n_{mn} \end{bmatrix} \end{array} \tag{4}$$

The elements of the normalized matrix (N) are determined using the equation:

(a) For Benefit type criteria (a higher value of the criterion is preferable)

$$n_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \tag{5}$$

(b) For Cost type criteria (a lower value of the criterion is preferable)

$$n_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \tag{6}$$

x_{ij}, x_i^+ *and* x_i^- are the elements from the initial decision matrix(X), for which x_i^+ and x_i^- are defined as:

x_i^+ =max $(x_1, x_2, \dots, x_m)$ and is the maximum value of the observed criterion according to the alternatives.

x_i^- =min $(x_1, x_2, \dots, x_m)$ and is the minimum value of the observed criterion according to the alternatives.

Step 3. Calculation of the elements from the weighted matrix (V). The elements from the weighted matrix (V) are calculated on the basis of the expression.

$$v_{ij} = w_i.(n_{ij} + 1) \tag{7}$$

Where n_{ij} are the elements of the normalized matrix (N), w_i is the weight coefficients of the criteria.

$$V=\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \dots & v_{2n} \\ \vdots & \dots & \dots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}=\begin{bmatrix} w_1.(n_{11}+1) & w_2.(n_{12}+1) & \cdots & w_n.(n_{1n}+1) \\ w_1.(n_{21}+1) & w_2.(n_{22}+1) & \dots & w_n.(n_{2n}+1) \\ \vdots & \dots & \dots & \vdots \\ w_1.(n_m+1) & w_1.(n_{m2}+1) & \cdots & w_n.(n_{mn}+1) \end{bmatrix} \tag{8}$$

Step 4. Determining the border approximation area matrix (G). The Border Approximation Area (BAA) for each criterion is determined according to the Eq. (6)

$$g_i=\left(\prod_{j=1}^{m} v_{ij}\right)^{1/m} \tag{9}$$

where v_{ij} are the elements of the weighted matrix (V), and m is the total number of alternatives. After calculating the value g_i for each criterion, a border approximation area matrix G (19) is formed with the format n 1 (n is the total number of criteria according to which the selection is made from the alternatives offered).

$$G=\begin{matrix} C_1 & C_2 & \dots & C_n \\ [g_1 & g_2 & \cdots & g_n] \end{matrix} \tag{10}$$

Step 5. Calculation of the distance of the alternative from the border approximation area for the matrix elements (Q)

$$Q=\begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \tag{11}$$

The distance of the alternatives from the border approximation area (q_{ij}) is determined as the difference between the elements in the weighted matrix (V) and the value of the border approximation area (G).

$$Q = V - G = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} - \begin{bmatrix} g_1 & g_2 & \cdots & g_n \\ g_1 & g_2 & \cdots & g_n \\ \vdots & \cdots & \cdots & \vdots \\ g_1 & g_2 & \cdots & g_n \end{bmatrix} \tag{12}$$

$$Q = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \cdots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \cdots & v_{2n} - g_n \\ \vdots & \cdots & \cdots & \vdots \\ v_{m1} - g_1 & v_{m2} - g_2 & \cdots & v_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \tag{13}$$

where g_i is the border approximation area for criterion C_i, v_{ij} is the weighted matrix of the elements (V), n is the number of criteria, m is the number of alternatives.

Alternative A_i could belong to the border approximation area (G), upper approximation area (G^+) or lower approximation area (G^-), that is, $A_i \epsilon \{GVG^+VG^-\}$. The upper approximation area (G^+) is the area which contains the ideal alternative (A^+), while the lower approximation area (G^-) is the area which contains the anti-ideal alternative (A^-) (Fig. 2).

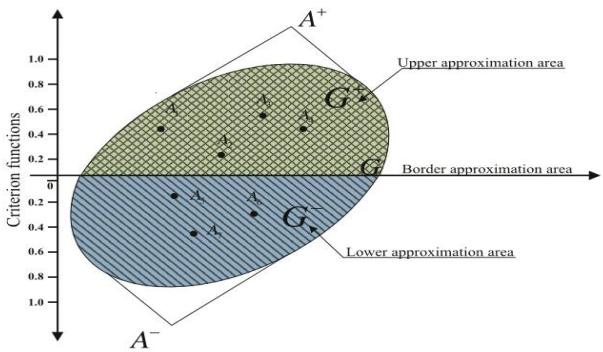

Fig. 2 Presentation of the upper (G^+), lower (G^-) and border (G) approximation areas.

The belonging of alternative A_i to the approximation area (G, G^+ or G^-) is determined on the basis of Eq. 14

$$A_i \epsilon \begin{cases} G^+ & eğer\ q_{ij} > 0 \\ G & eğer\ q_{ij} = 0 \\ G^- & eğer\ q_{ij} < 0 \end{cases} \tag{14}$$

In order for alternative A_i to be selected as the best in the set, it is necessary for it to have as many criteria as possible belonging to the upper approximate area. If the value $q_{ij} > 0$ that is $q_{ij} \epsilon G^+$, then alternative A_i is near or equal to the ideal alternative. If the value $q_{ij} < 0$, that is $q_{ij} \epsilon G^-$, it shows that alternative A_i is near or equal to the anti-ideal alternative.

Step 6. Ranking the alternatives. A calculation of the values of the criterion functions for the alternatives Eq. 15 is obtained as the sum of the distance of the alternatives from the border approximation areas (q_i). By calculating the sum of the elements of matrix Q by rows we obtain the final values of the criterion functions of the alternatives.

$$S_i = \sum_{j=1}^{n} q_{ij} \qquad j=1,2,\ldots,n, \qquad i=1,2,\ldots,m \tag{15}$$

where n is the number of criteria, m is the number of alternatives.

4. Sample Application and Analysis

All DG technologies have advantages and disadvantages. Considering the fact that there are lots of factors about DG technology selection, we preferred using multi-criteria decision methods in a

systematic hierarchy. In this study, 10 important criteria affecting the system were determined and collected under four main headings as follows.

4.1. Evaluation Criteria for Cogeneration Systems

1. Economical

a. Investment cost: Including both purchase and installation costs. (C_1)

b. Total annual cost: Operating and maintenance costs (C_2)

c. Payback period: Time period required to cover initial investment. (C_3)

2. Technical

a. Efficiency: Amount of useful energy can be obtained from the source. (C_4)

b. Continuity: Suitability to meet energy needs continuously. (C_5)

c. Source state: Whether the energy source is easy to obtain or not. (C_6)

3. Environmental

a. Air pollution: Greenhouse gas emission causing global warming, acid rains and etc. (C_7)

b. Noise pollution: Continuous noise during generation process. (C_8)

4. Social

a. Footprint: Required space for generating system. (C_9)

b. Safety: Whether the system is safe for surrounding or not. (C_{10})

These criteria were prioritized with AHP based on expert knowledge and 5 alternative DG technologies were tried to determine the ideal alternative by MABAC method considering these criteria weights (Fig. 3).

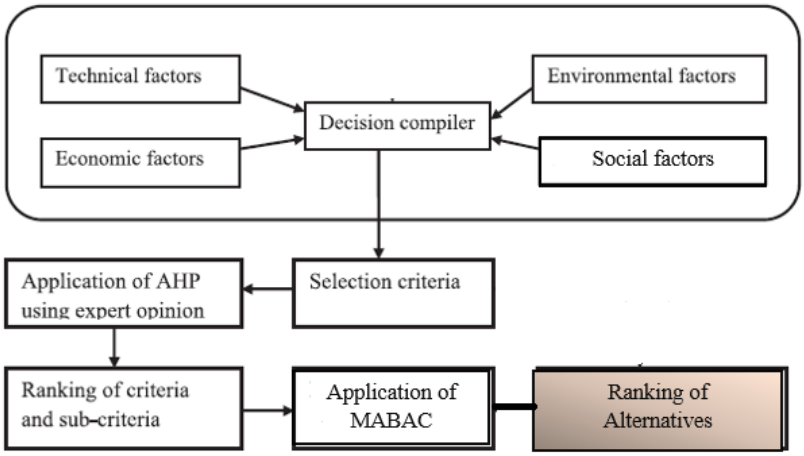

Fig.3 Proposed framework of present study (Inspired from Sindhu et al.[13])

To select an ideal DG system of combined heating and power for especially residential and commercial buildings, the candidate technologies which are the trend in todays and future applications for small-capacity DG units. The following DG systems and a separate generation system have been considered in this paper.

4.2. Candidate Alternatives

Five alternatives of trigeneration systems derived from different energy sources are selected to compare each other.

1. Traditional CHP system with one of reciprocating engines (RE)
2. CHP system based on micro gas turbine (MT)
3. Fuel cell CHP system (FC)
4. CHP system with Renewable Energy Sources
a. Solar Photovoltaic (PV)
b. Wind Turbine (WT)

4.3. Results

Assignment of weights is an important part of any research because it gives measure for relative importance to the others. The ranking evaluation is carried out following the steps given in section 4.3.

Opinions of 3 decision makers were used for establishing comparison matrices of both main criteria and sub criteria. Decision makers' opinions are combined using geometric mean.

Table 2. Weights of Main Criteria

Main Criteria	***Economical***	***Technical***	***Environmental***	***Social***	***Priority Value***
Economical	1	1,44	2,28	5,94	0,4025
Technical		1	3	5,94	0,3589
Environmental			1	5	0,1842
Social				1	0,0542
CR	**0,05**				

The consistency ratio CR is given under each 2 comparison matrix. Table 2 shows the weights of main criteria while Table 3.1-3.4 displays sub-criteria weights for each main criteria.

According to Table 2, economic criterion has the highest value among the weighted main criteria while the second one is technical criterion followed by environmental and social criteria, respectively.

As seen from Table 3.1 to 3.1, among the weighted sub-criteria, the efficiency criterion has the highest priority value where the second one is the investment cost. Air pollution criterion is following them as the third one whereas the footprint criterion is the last one.

Table 3.1. Weights of Sub-criteria (Economical)

Sub-criteria	***IC***	***TAC***	***PP***	***Priority Value***
Investment cost (IC)	1	1,65	3,30	0,2052
Total annual cost (TAC)		1	3	0,1426
Payback period (PP)			1	0,0546
CR	**0,01**			

Table 3.2. Weights of Sub-criteria (Technical)

Sub-criteria	***E***	***C***	***SS***	***Priority Value***
Efficiency (E)	1	3	5	0,2312
Continuity (C)		1	2,27	0,0857
Source state (SS)			1	0,0419
CR	**0,01**			

Table 3.3. Weights of Sub-criteria (Environmental)

Sub-criteria	***AP***	***NP***	***Priority Value***
Air Pollution (AP)	1	4,48	0,1506
Noise Pollution (NP)		1	0,0336

Table 3.4. Weights of Sub-criteria (Social)

Sub-criteria	***F***	***S***	***Priority Value***
Footprint (F)	1	0,26	0,0110
Safety (S)		1	0,0432

Decision matrices were created by assigning a value between 1 and 10 for each alternative to each criterion with decision makers' opinion. Decision makers' opinions were combined with the geometric mean and the values in Table 6 were obtained. The maximum ($\mathbf{X_i^+}$) and minimum ($\mathbf{X_i^-}$) values of the criteria were obtained from the determined alternative values.

Table 4. Decision matrix and Maximum-Minimum values

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
RE	2,621	7,652	2,621	7,652	6,649	6,649	8,320	8,320	7,319	6,952
MT	4,641	6,257	5,944	6,649	7,652	6,649	6,257	6,649	6,952	6,952
FC	8,618	6	7,319	9,322	9,322	5,646	3,634	4,642	5,313	5,518
SPV	6,952	8,653	9,322	4,309	3,302	7,652	2,621	2,289	6,952	8,962
WT	5,646	3,302	4,642	5,313	5,313	8,653	1,26	5,646	2,289	5,944
$\mathbf{X_i^-}$	2,621	3,302	2,621	4,309	3,302	5,646	1,26	2,289	2,289	5,518
$\mathbf{X_i^+}$	8,618	8,653	9,322	9,322	9,322	8,653	8,320	8,320	7,319	8,963

Table 5 was obtained from Equations 5 and 6.

Table 5. Normalized Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
RE	1,000	0,187	1	0,667	0,556	0,334	0	0	0	0,416
MT	0,663	0,448	0,504	0,467	0,723	0,334	0,292	0,277	0,073	0,416
FC	0,000	0,496	0,299	1	1	0	0,664	0,61	0,399	0
SPV	0,278	0	0	0	0	0,669	0,808	1	0,073	1
WT	0,496	1	0,698	0,200	0,334	1	1	0,443	1	0,124

Table 6 was calculated by using Equation 7 while G value was obtained from Equation 9 and listed on Table 7.

Table 6. Weighted Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
RE	0,410	0,169	0,109	0,385	0,133	0,056	0,151	0,034	0,011	0,061
MT	0,341	0,207	0,082	0,339	0,148	0,056	0,195	0,043	0,011	0,061
FC	0,205	0,213	0,071	0,462	0,171	0,042	0,251	0,054	0,015	0,043
SPV	0,262	0,143	0,055	0,231	0,086	0,07	0,272	0,067	0,012	0,086
WT	0,307	0,285	0,093	0,278	0,114	0,084	0,301	0,049	0,022	0,049

Table 7. Boundary Similarity Area for each criterion

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
G	0,297	0,198	0,08	0,329	0,127	0,06	0,227	0,048	0,014	0,058

The distances of the alternatives from boundary similarity are calculated by Equation 12 as seen on Table 8.

Table 8. Distances of Alternatives from Boundary Similarity

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	S_i
RE	0,113	-0,029	0,03	0,056	0,006	-0,004	-0,076	-0,014	-0,003	0,003	0,0819
MT	0,044	0,09	0,002	0,01	0,021	-0,004	-0,032	-0,005	-0,002	0,003	0,0449
FC	-0,092	0,015	-0,09	0,133	0,044	-0,018	0,024	0,006	0,001	-0,015	0,0904
SPV	-0,035	-0,055	-0,025	-0,098	-0,041	0,010	0,045	0,019	-0,002	0,028	-0,1544
WT	0,01	0,087	0,013	-0,052	-0,013	0,024	0,074	0,0005	0,008	-0,01	0,1427

Finally, the alternatives are ranked by calculating the value of S_i with Equation 15, which is the sum of the distances of the alternatives from the boundary similarity areas.

5. Conclusions

According to S_i values, the obtained ranking order of DG options is WT and following FC, RE, MT and lastly, PV. WT is selected for its environmental friendship use whereas it could not be as efficient as FC or RE. Although PV is environmentally friendly, it the last one in order because of the high initial investment cost. FC is in the second order due to its high investment cost sourced from its immature technology despite its high efficiency and environmental friendliness.

A hybrid energy system which is a photovoltaic array coupled with a wind turbine would create more output from the wind turbine during the winter, whereas the solar panels would produce their peak output during the summer [16]. Hybrid solar and wind powered units are increasingly being used for traffic signage, particularly in rural locations, as they avoid the need to lay long cables from the nearest mains connection point.

As hybrid energy systems often provide greater economic and environmental returns than wind or solar stand-alone systems by themselves, in subsequent works hybrid energy systems can also be included in the rank.

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A CLOUD-BASED DECISION SUPPORT SYSTEM FOR OPTIMIZING THE COST OF CITY-BUS OPERATIONS IN URBAN ROAD TRANSPORT ORGANIZATIONS

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ABSTRACT

Optimizing the cost of bus operations is one of the major issues in any Urban Road Transport Organizations (URTOs). In this study a Cloud-based Decision Support System (C-DSS) is developed for making efficient decisions on location of depots (adding new locations and removing existing ones) and allocation of city-buses to depots with an objective of minimizing the cost of operations comprising (a) dead-kilometre cost, (b) fixed cost associated with introducing new depots, and (c) salvage value due to closing the depots. Due to the computational difficulty in obtaining exact solution for the decision problem on location of depots (LD) and allocation of buses to depots (ABD), an efficient and simple greedy heuristic algorithm is implemented in the model management module of the proposed C-DSS for LD-ABD problem. Furthermore, as the cloud computing extends the notion of desktop computing to the scalability and virtualization of distributed processing servers on the internet, in this study, a C-DSS is proposed. The prototype C-DSS for LD-ABD problem of URTO is demonstrated for its workability and validity using pseudo data, generated by observing the LD-ABD problem of Bangalore Metropolitan Transport Corporation (BMTC), a major URTO in Karnataka, India.

Keyword: Allocation of Buses to Depots, Cloud-based Decision Support System, Dead-Kilometre Costs, Greedy Heuristic Algorithm, Location of Depots

Introduction

Urban passenger road transportation services provide vital public transport for the general public in major cities worldwide. The complexities associated with managing these services increase regularly as cities continue to grow. In addition theperformance of Metro Transport Corporations on select parameters for the financial period 2013-2014 (*Source:* RPSRTU 2015) given in Table 1 reveals that every Urban Road Transport Organizations (URTOs) often face the challenge of maintaining good service standards with minimal cost of operations. URTOs' operations cost comprises various cost components, including labour, fuel, dead-kilometre costs, and maintenance

costs of depots. It has been noted that fuel and labour costs are typically inelastic to passenger demand and do not provide much scope for minimization.

Table 1: The Performance of Metro Transport Corporations for the Financial Period 2013-2014

Performance Parameters	Metropolitan Transport Corporation (MTC)				
	Bangalore	Calcutta	Chennai	Delhi	Mumbai
Average Fleet Held (No.)	6603	718	3660	5341	4314
Average Age of Fleet (Years)	**5.3**	**5.7**	**5.1**	**6.3**	**7.6**
Passenger Carried (Lakhs)	17938.0	865.1	18068.0	15867.6	13068.0
Revenue Earning Kilometres (Rs.. Lakhs)	4795.9	215.7	3600.4	3165.2	2550.8
Total Revenue (Rs. Lakhs)	201394.23	6197.60	135486.14	120957.80	143510.38
Total Cost (Rs. Lakhs)	215146.98	23052.52	149679.69	46680319	218435.18
Net Profit/Loss (Rs. Lakhs)	-13752.75	-16854.92	-14193.55	- 345845.39	-74924.80
Revenue per Kilometre (Rs.)	41.99	28.73	37.63	38.21	56.26
Cost per Kilometre (Rs.)	44.86	106.87	41.57	147.47	85.63
Profit/Loss per Kilometre (Rs.)	-2.87	-78.14	-3.94	-109.26	-29.37

Furthermore, for each day, almost every URTOs in India incurs in the order of several thousand dead-kilometres. For example, refer Table 2 for the data on annual dead-kilometres for Bangalore Metropolitan Transport Corporation (BMTC), a major URTO in Karnataka, India. Hence, the costs associated with dead-kilometre provide the best opportunity for cost reduction for URTOs by optimally or efficiently allocating the buses to depots.

Table 2: The Year-wise growth of depots, number of vehicles, and dead-kilometres for Bangalore Metropolitan Transport Corporation (BMTC)

Year	Year wise the Physical Details on the Parameter					Dead-Kilometres in Lakhs[1]	Revenue per Kilometre in INR[2]	Cost per Kilometre in INR
	No. of Depots	Number of Vehicles			Kilometres per Litre (High Speed Diesel)			
		New	Scrapped	Held				
2009-10	33	1218	664	6093	4.11	268.60	25.62	24.11
2010-11	35	58	40	6111	4.01	309.51	29.02	27.92
2011-12	37	385	299	6162	3.98	199.16	32.29	31.83
2012-13	39	559	268	6431	3.84	176.24	35.80	38.99
2013-14	39	838	492	6777	3.82	135.02#	41.99	44.86
2014-15	40	201	327	6642	3.78	194.18		

incomplete one [data based on upto Nov. only]
[1] Lakh = 0.1 million
[2] 1 INR = US$66 as on 24 August 2015
Source: https://www.mybmtc.com/performance-indicator (accessed on 11th Sep, 2015), BMTC (2014) & RPSRTU (2015)

In practice, the decision on allocation of buses to depots to minimize the dead-kilometre costs is not independent of the decision on the location of the depots, nor would it be efficient for them to be treated independently. That is, minimizing dead-kilometre is closely linked with

locating the depots, which, in turn, is influenced by closing existing depots and opening new ones in a different location. Thus, the necessity of analytical methodologies for the Locations of Depots (LD) and Allocation of Buses to Depots (ABD), a strategic level decision problem of URTOs, arises.

Though there are studies on the decision problem on allocation of buses to depots with an objective of minimizing dead-kilometre in India (Raghavendra and Mathirajan 1987; Sridharan 1991; Vasudevan 1993; Prakash et al.,1999; Mathirajan et al.,2010), there is no study on the decision problem that simultaneously considers location of depots (adding new locations and removing existing ones) and allocation of buses to depots (LD-ABD) with an objective of minimizing the sum of dead-kilometre costs and fixed costs of opening new depots less salvage costs of closing existing depots, particularly with reference to Indian URTOs. To address this research gap, the decision problem on LD-ABD is taken up in this study and proposed a Cloud based Decision Support System (C-DSS) to solve the LD-ABD problem.The proposed C-DSS can solve the problems: (a) Allocation of Buses to Depots (ABD) to minimize the total dead-kilometre or Total dead-kilometre costs, and (b) LD-ABD to minimize the sum of dead-kilometre costs and fixed costs of opening new depots less salvage costs of closing existing depots.

The organization of the paper is as follows: A closely related literature review observed in URTOs is presented in section 2. Definition of the LD-ABD problem considered in this study and the assumptions are given in section 3. The proposed C-DSS for ABD and LD-ABD is presented in section 4. Verification, testing and validation of the proposed C-DSS is discussed in Section5. The final section concludes the study.

Closely Related Literature Review

In this section, the closely related literature review is carried out for the decision problems on (i) allocation of buses to depots (ABD), and (ii) location of depots and allocation of buses to depots (LD-ABD).

A Review on ABD Problem of URTO

The ABD problem was formulated with two objectives: (i) minimizing the cumulative distance travelled by all buses from the depots to the starting points of their routes as primary objective, (ii) minimizing the maximum distance travelled by individual buses from the depots to the starting points of their respective route as secondary objective, by Sharma and Prakash (1986), and Prakash et al. (1999). This formulation has (a) an implementation difficulty in deciding which

bus should get allocated to which depot, (b) the implicit assumption that every bus starts and ends in the same terminal (which is not true in practice, particularly in Indian scenarios), and (c) been demonstrated with their solution process on a tiny instance without any computational experiments to guarantee to obtain exact solution (or non-dominated solution) for real life size problems.

Raghavendra and Mathirajan (1987), Sridharan (1991), and Vasudevan et al. (1993)considered an ABD problem, as observed in Bangalore Transport System (BTS), MDK corporation of Ahmedabad, and Pallavan Transport Corporation of Chennai respectively and proposed (0-1) integer Linear Programming model with an objective of minimizing total dead kilometer.These studies assumed that the proposed model satisfies the unimodular property and solvedas linear programming problem model for the large scale ABD problem related to the respective URTO considered by them. However, there is a possibility that these models do not follow the unimodular property when we have to incorporate some additional constraints such as conditional constraint, co-requisite constraint, etc.,that might be required for certain buses and their allocation to certain depotson the decision on allocation of buses to depots. Inclusions of more such real life constraints in these models lead the decision making problem to a computationally intractable one, as the number of 0-1 variables in the real-life problem runs to several thousands. Keeping in view the computational difficulties in obtaining exact solution for a complete real life problem on ABD a few researchers proposed heuristic algorithms for efficient allocation of buses to depots (Mathirajan, 1993; Vidya Shankar et al.1989, Mathirajan et al. 2010).

Eliiyi et al. (2012) and Naisbov et al. (2013) defined two types of ABD problems and proposed Integer Programming model with an objective of minimizing total dead-kilometre and demonstrated its utility using the real-life data obtained from Izmir City Bus Service, in Turkey.

One of the important real life requirements, on the same type of buses (based on the bus characteristics such as brand, size, age, Air-Conditioned (AC), Non-AC, diesel, electric, Compressed Natural gas (CNG), and so on) should get allocated to one depot only, is not explicitly considered in all the earlier studies reviewed here. However, Hsu (1988) introduced this specific requirement and appropriately extended the ABD problem studied by Sharma and Prakash (1986).

Van der Perre et al. (1996) considered simple ABD problems and subsequently added additional dimensions such as optimizing the required number of depots, and optimizing the allocation of buses considering the constraint on the type of buses. They proposed mixed integer programming model for optimizing (a) the number of depots, and (b) the overall dead-kilometres.

Due to the computational difficulties, they proposed hierarchical optimization and heuristics. The proposed models were demonstrated empirically using the real life data collected from Bangkok Mass Transit Authority (BMTA). Djiba et al. (2012) proposed (0-1) mixed integer linear programming model with the requirement on the type of buses while allocating to depotsfor the main public urban transportation company in Dakar and demonstrated the potential savings.

In all the above studies, the authors did not considered the operational cost due to dead kilometer as criterion for evaluating the alternatives. That is, in reality the operational cost is based on the dead-kilometre covered by a bus and fuel cost per kilometre incurred for a bus, which is a function of a type of bus and its age. So, minimizing total dead-kilometre cost is more appropriate objective than the one of minimizing the total dead-kilometre. Accordingly, Agarwal and Dhingra (1989) studied the impact of increasing the existing depot capacity while optimally allocating the existing number of buses to depots with an objective of minimizing the sum of the total capital cost to be incurred in augmenting capacities of the depots and the total dead-kilometre cost covered by all buses over a planning period.

Kepaptsoglou et al. (2010) developed a Decision Support System for ABD problem with quadratic programming model to optimally allocate the buses to depots with the main objective of minimizing the cost of dead-kilometres travelled by all the buses. The DSS proposed by them was implemented for the case of the Athens (Greece) bus network and they showed considerable monetary savings.Kontou et al. (2014) extended the study of Kepaptsoglou et al. (2010) by considering particularly the depot operating cost per bus, applicable to Athens (Greece) bus network and proposed mixed integer-quadratic programming model. Due to the computational intractability of the proposed model they proposed meta-heuristic and demonstrated the quality of the solution for the ABD problem in comparison with the optimal solution being obtained on a set of problems using commercial solver.

From the analysis of the review presented above, the ABD component of the problem considered in this study optimizes the total dead-kilometre cost, instead of optimizing total dead-kilometre, carried out in the earlier studies related to Indian URTOs.

A Review on LD-ABD problem of URTO

Maze at al. (1982, 1983) proposed a (0-1) mixed integer programming model to minimize total dead-kilometre costs, crew/driver relief costs, depot operating, and capital costs. Due to the

computational intractability, they solved the problem in two stages using transportation approach in the first stage and heuristic in the second stage to minimize the total costs considered in their study. They successfully implemented their methodology to a transit system in Detroit, MI.

Ball et al. (1984) implemented a heuristic method for addressing a large number of possible depot location problem, with the objective of minimizing the sum of capital cost (associated with construction of depots), dead-kilometre cost (associated with allocation of buses to depots), and crew relief costs (observed in Southeastern Pennsylvania). Waters et al. (1986) addressed the location of depots problem, by considering both dead-kilometre costs and capital costs for constructing depots, to determine depot locations and the respective allocation of buses by using discrete space models. Prakash and Saini (1989) formulated LD-ABD problem with the primary objective of minimizing the capital cost of constructing a new depot plus the present value of the total dead-kilometre cost over the entire planning horizon and secondary objective of minimizing the maximum distance among the distances covered by individual buses from depots to starting points of their trips.

Uyeno and Willoughby (1995) proposed a (0-1) mixed integer programming model to determine optimum (a) location of the depots, (b) number of depots, and (c) allocation of buses to depotswith an objective of minimizing dead-kilometre costs and capital costs of introducing depots. They demonstrated the workability of their proposed model for the Vancouver Regional Transit System (VRTS), Canada and claimed huge monetary savings per year in operating expenses. Willoughby and Uyeno (2001) addressed the problem with the additional constraint that the buses of specific types should be allocated to a single depot, in the LD-ABD problem. Willoughby (2002) proposed (0-1) mixed integer programming model to analyze the location of depots and the allocation of buses to depots with an objective of minimizing the sum of the dead-kilometre cost, capital cost, and salvage values for VRTS, Canada.

From the analysis of the closely related literature review presented in this section, there is no study carried out in India related to LD-ABD problem considered in this study, though there are several studies looking at ABD problem in Indian context. This study attempts to fill this gap.

Definition of the LD-ABD Problem of URTOs and Assumptions

Before exactly defining the research problem considered, we first provide some details of LD-ABD problem relevant to the case study. This paper focuses on the operations of Bangalore

Metropolitan Transport Corporation (BMTC). BMTC has registered phenomenal growth in the last about 3 decades, from 8 depots and about 1200 buses in 1986 (Raghavendra and Mathirajan, 1987) to more than 40 active depots and 6520 buses in 2015 (BMTC Website, 2015).

In addition to the increased number of depots from 8 in 1986 to 40 today, the BMTC closed a few existing depots mainly due to the continuous expansion of the city as well as the growing population of the Bangalore city. For example, during 1986 there were three adjacent depots in KH Road (named as KH Road 1, KH Road 2, KH Road 3 with depot-capacity of 129, 137, and 140 buses respectively). Over the period, the location of KH Road has become almost centre part of the Urban City Bangalore. In order to avoid the congestions, particularly in the city centre, and to facilitate smooth service for passengers, the BMTC closed one of the Depot in KH Road and built an interstate bus station called Santhi-Nagar Bus Station with various business activities. Keeping such developments in mind, the research problem on location of introducing new depots and eliminating existing depots and allocation of buses to depots can be defined as follows:

Given the following:

- a set of existing depots and their capacities,
- a set of possible depots to be eliminated from the existing ones,
- a set of possible new depots and their capacities,
- a set of existing buses,
- a set of new buses,
- Bus-depot wise the dead-kilometre incurred while bus gets allocated to depot,
- Bus wise operational cost per kilometre irrespective of which depot it is being allocated,
- Fixed cost associated for each of the possible new depots, and
- Salvage cost associated with each of the possible depots to be eliminated

The objective of this study is to propose Decision Support Systems (DSS) to decide optimal choice of the depots for both opening and closing and allocation of buses to the depots for minimizing the sum of dead-kilometre cost, total capital cost due to introducing new depots and total salvage cost by eliminating existing depots.The following assumptions are made based on Indian situations for the development of solution methodologies for the research problem considered in this study:

- There is no change in the existing routes of the buses.

- Apart from considering the dead-kilometre issues based on the night parking perspective, mid-day parking depot assignment problem due to shifts in route-bus demands through the day is also worth to consider. However, this is not considered in this study.
- The dead-kilometres associated with a bus which comes to a depot during day-time for its maintenance needs are not considered in the proposed solution methodologies. The service period of these buses are different, particularly these buses are used to provide passenger-services covering maximum period in the night time and generally parked a few hours near the Police station due to security reasons.
- Splitting of the route is allowed, i.e., if a particular route, say route#276 has 12 buses, the model may assign x number of buses to one depot and ($12-x$) number of buses to another depot. When services are initiated, a few buses will commence from the starting terminal and the rest from the ending terminal. This indicates that for each bus route, not all buses will necessarily originate from the same depot.
- Depot operating cost per bus is assumed to be same for all the depots. Furthermore, every depot has all the required facilities for providing maintenance and other service activities for any types of bus. So the types of bus does not have any effect on deciding the choice of the depot for allocation and due to this any bus can be assigned to any depot.
- The total capacity of all the available depots should be greater than the total number of all the buses in the system to be allocated.
- Other costs such as bus breakdown costs, driver relief cost (if any), etc. are not considered.

The Proposed Cloud-based DSS for LD-ABD

Decision Support Systems (DSS) is a computerized system that provides support to decision makers during the problem solving process by retrieving data and testing alternatives. Today the DSS is becoming popular for every decision makers to host part or all of their DSS in a cloud computing environment. National Institute of Standards and Technology (NIST) defines cloud computing as “a model for enabling ubiquitous, convenient, on demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications,

and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance, 2011).

Cloud computing provides different types of services in three main layers such as SaaS (Software as a Service, PaaS (Platform as a Service, IaaS (Infrastructure as a Service and provides many chances for enterprises by offering a range of computing services. Cloud computing usually has a "pay as you go" model (Furht and Escalante, 2010) so that the customer only pays for the services they use. One of the main advantage in cloud computing is that the cloud computing allows a customer to hire in only the required computational capacity at the required time frame. Due to scalable and elastic features of cloud computing, this has opened up for new flexible and cost effective web applications. One of the main advantage in cloud computing is that the cloud computing allows a customer to hire in only the required computational capacity at the required time frame. By utilizing the concept of cloud computing, the objective defined in this study can be addressed without owning any cluster hardware and in that way save money, electricity and other resources for URTS.

Accordingly, the proposed Cloud based DSS(C-DSS) is developed using latest web technologies like Angular.js, PHP, HTML and CSS with a backend MySQL databaseand with a user-friendly web interface which can be used in any browser. The Proposed C-DSS is developed as a SaaS model in the cloud and it is currently deployed in Amazon Web Services (AWS) Cloud, which enables the users to access it from anywhere using any devices. Figure 1 shows the deployment architecture for this proposed C-DSS system which is deployed over the internet for easy access. The architecture is based on a simple 2-tier architecture with web layer and database layer. The web application is integrated with cloud watch, notification module and email module for external communication. The database is deployed in failover mode with two instances one as master and the other in standby mode.

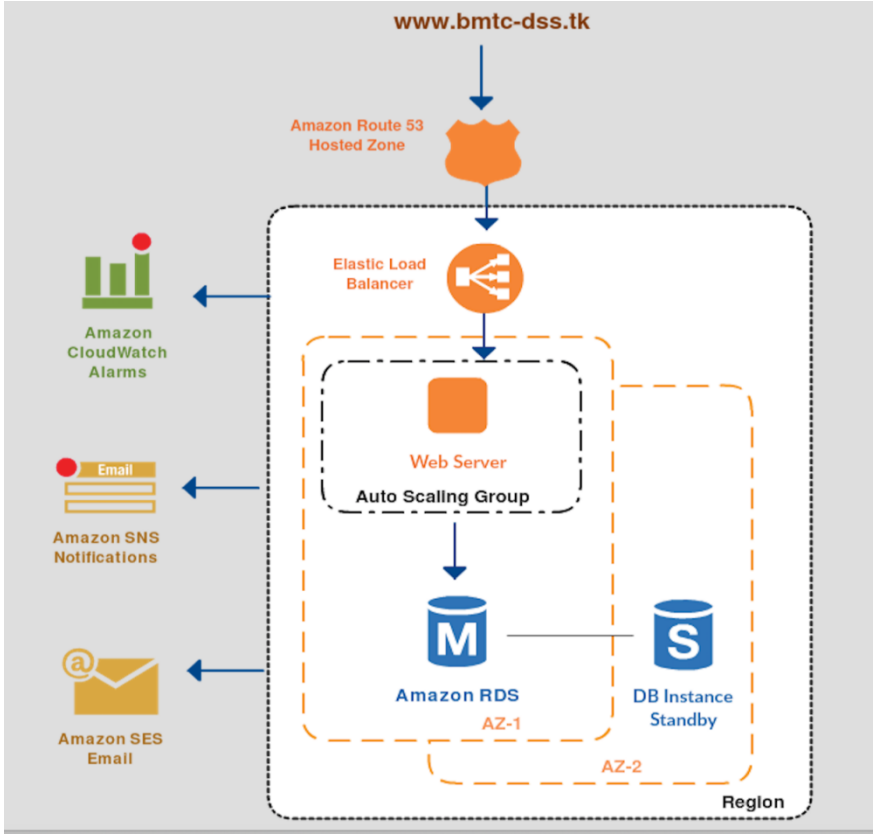

Figure 1 : Proposed architecture for the proposed C-DSS

This proposed C-DSS software can be used by any number of URTOs without any installation or any deployment of this software in their premisesas a service. The system requirements for the proposed C-DSS to support maximum of 8000 buses, 200 terminus and 100 depots problem of URTS will be as follows (To address large scale to this data, additional RAM needs to be deployed in the machine):

- Public Cloud: Amazon Web Services (AWS)
- Hardware: 2 core CPU
- Memory: 8 GB RAM
- Operating System: Amazon Linux (any latest version available in the region)
- Software: Apache V2.4, PHP V5.6, MySQL 5.5.42, phpMyAdmin version 4.4.10

The proposed C-DSS consists of the five integrated modules: (i) Web interface Module, (ii) Control Module, (iiii) Database Management Module, (iv) Model Management Module, and

(v) Report Generation Module. The conceptual view of these five interconnected modules is schematically shown in Figure 2 with its details as follows:

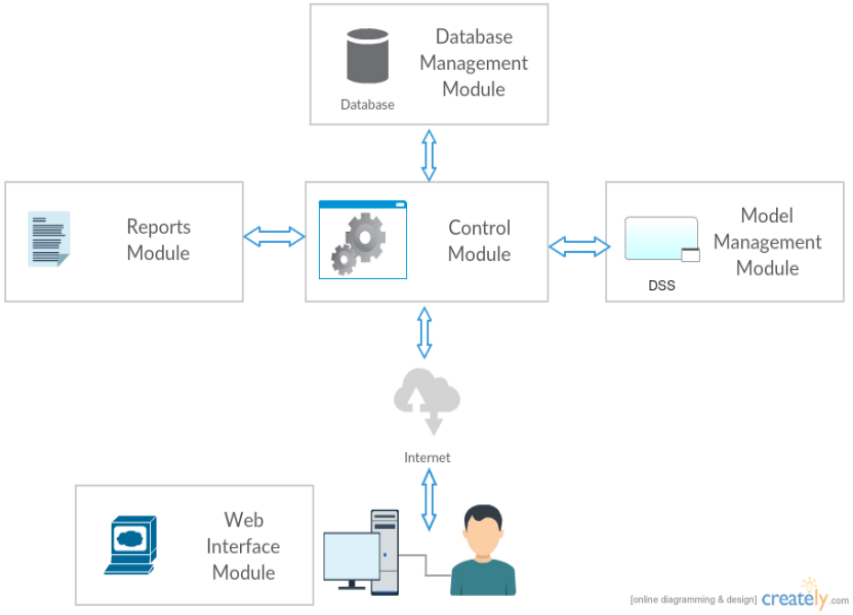

Figure 2 : A Conceptual view of the Proposed C-DSS

Module 1 : Web Interface Module:

The web interface module provides all the required user interface in a standard web browser. The main menu of this interface is shown in Exhibit 1. Accordingly, the user can perform the following operations:

- Depot Management – This interface is provided to add new depots, modify the existing depot and delete the existing depot(s) information. It also does the UI level validation on the information entered by the user. A new depot consists of depot code, depot name, current capacity of the depot, maximum capacity possible, and other essential details. The web interface for 'Depot Management' operation is shown in Exhibit 2.
- Terminus Management – The user can add new terminus by using the form provided in this module. The terminus code and terminus name are essential inputs for each of the terminus. It also provides options to edit the existing terminus information and delete the

terminus details. Exhibit 3 represents the "Terminus Management"of web interface module.

- Bus Management – The web interface module for "Bus Management" operation is used by the user to add new buses into the system. It provides an interface which will allow the user to select the depot, select the start and end terminus (a drop-down menu to choose from the existing information) and fuel cost for the bus. The user can also edit and delete the bus information. The buses are managed through the web interface, existing depot and bus allocation as shown in Exhibit 4.
- Add Restrictions –Any information related to restriction/constraint in allocating bus(es) to Depot(s) will be given in this option.
- Allocation of Bus to Depots (ABD) – Execute the algorithm incorporated in the Model Management Module for efficiently allocation the given number of buses to given number depots considering the data stored in the Database Management Module
- What if Analysis – User is allowed in this option to modify the data or modify the system generated solution to learn what will be effect of the overall cost.
- Location of Depots and Allocation of Bus to Depots (LD-ABD) – Provides an user interface to mark the depots for closing, open prospective depots, add more buses/terminuses and execute the algorithm incorporated in the Model Management Module for efficiently deciding closing existing depots, opening new depots, and allocation of the given number of buses (comprising both existing and new buses) to given number depots (comprising both existing and new depots) considering the data stored in the Database Management Module.
- Reports – This option provides the user to view and download various reports in excel format.

Module 2: Control Module:

The control module receives the user's request from the web interface module and directs the received request to the respective modules of the proposed C-DSS. For every request received by the control module, in general, the following steps are carried out:

Step 1: Gets the request from the user interface.

Step 2: Checks the type of request.

Step 3: If the request is to add information related to depots, buses or terminus, it will invoke the respective operation in the database management module.

Step 4: If the request is related to view the information, it requests the database management module to retrieve the data from the database. Then the control redirects to the user interface module with the data and the user can view the data.

Step 5: If the request is to delete the information, it requests the database management module to delete the respective record in the database. An appropriate message is also displayed in the UI through web user interface module.

Step 6: If user requests to execute the algorithm for the data, the control redirects to the model management module to fetch the appropriate model/algorithm and execute the same.

Step 7: If the report options are selected in the user interface, the control generates the reports using the Reports Module and allows the user to download it in excel format.

Exhibit 1 : Web Interface Module

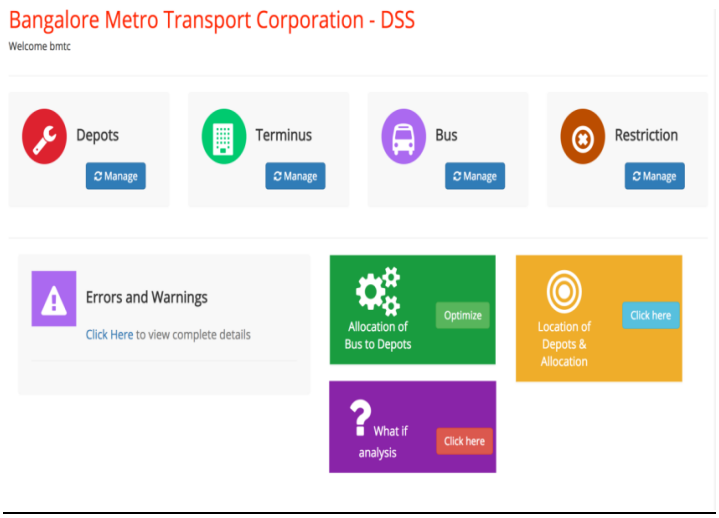

Exhibit 2 : Web Interface Module – Depot Management

Depots

Create New | Upload | Search | Search

No	Code	Name	Curr. Capacity	Max. Capacity	Oper. Cost	Fixed Cost	Salvage Cost	Action
1	D1	Depot1	3	5	0	0	180000	Edit Delete
2	D2	Depot2	7	0	0	0	0	Edit Delete
3	D3	Depot3	5	8	0	0	200000	Edit Delete
4	D4	Depot4	10	10	0	175000	0	Edit Delete
5	D5	Depot5	8	8	0	100000	0	Edit Delete

Exhibit 3 : Web Interface Module – Terminus Management

Terminus

Create New | Upload | Search | Search

No	Terminus Code	Terminus Name	Distance From/To Depot	Action
1	BBS	Bangalore Bus Station	Manage Distances	Edit Delete
2	CMT	City Market	Manage Distances	Edit Delete
3	GNR	Gandhi Nagar	Manage Distances	Edit Delete
4	MBS	Malleswaram Bus Station	Manage Distances	Edit Delete
5	SBS	Shivajinagar Bus Station	Manage Distances	Edit Delete

‹ 1 2 ›

Exhibit 4 : Web Interface Module – Bus Management

Existing Depot & Bus Allocation

Create New | Upload | Search | Search

No	Depot Code	Route No.	Start Terminus	End Terminus	Fuel Cost	Action
1	D1	R1	SBS	BBS	11	Edit Delete
2	D1	R2	CMT	CMT	12	Edit Delete
3	D1	R3	MBS	BBS	11	Edit Delete
4	D2	R4	GNR	SNR	11	Edit Delete
5	D2	R5	SNR	GNR	12	Edit Delete

Module 3: Database Management Module:

This module captures and maintains all the required data for efficiently (a) ABD, and (b) LD-ABD problem with an objective of minimizing the cost of operations comprising (a) dead-kilometre cost, (b) fixed cost associated with introducing new depots, and (c) salvage value due to closing the depots. The database captured is as follows:

Depot Table:This table consists of the values of the fields: Division name, Depot code, Depot name, Current capacity, Maximum possible capacity, Operating cost, Salvage cost if the management decided to close the depot activity, and Fixed cost if the management introduces new depot. The structure of the Table along with attributes' definition is given in Exhibit 5 and an auto increment field is provided by the database for each depot as a primary key.

Terminus Table: This Table stores the values of Terminus code, and Terminus name with the structure shown in Exhibit 6.The Field: 'id' in Exhibit 6 is an auto increment field assigned for each terminus by the database. Terminus-Depot Table: This Table stores the distance between each terminus to each of the depots. Accordingly this table stores each terminus code wise the distance values for each of the depots. The structure of the table along with scheme of the table is given in Exhibit 7

Bus Table: The Bus Table stores all the information relevant to the bus such as Bus (Route) number, Depot code (indicates that the bus is currently allocated in that depot), Start Terminus, End Terminus, and Fuel cost per km.The structure of the Table along with scheme of the Table is given in Exhibit 8. Result Table: Once the proposed DSS generates the results, it is stored in this table. Using the results stored in Result-Table, various reports are generated using the 'Report Generating Module'. The structure of this Result-Table is shown in Exhibit 9.

Module 4: Model Management Module:

The most important module in the proposed C-DSS is model management module. Due to the computational complexity in obtaining optimal solution for LD-ABD, particularly for large scale real problems, a simple greedy heuristic algorithm is incorporated in the proposed C-DSS. In addition, a what-if analysis is also incorporated in the model management module. The details on the heuristic algorithm proposed for LD-ABD problem for URTO and the what-if analysis features are as follows:

Exhibit 5 : Depot Table

Sl. No	Name	Type	Size	Description
1.	serialno	Integer	5	Serial number is an auto increment field which will be populated by the database automatically. This field is considered as a primary key in the table.
2.	code	Varchar	20	A unique depot code assigned to each depot is stored in this field
3.	name	Varchar	40	The name of the depot which usually denotes the location of the depot
4.	division	Varchar	5	The depots are located in various divisions within the city such as north, south, east and west
5.	Current capacity	Integer	5	Indicates the current capacity of the depot
6.	Maximum capacity	Integer	5	Refers how many number of buses that can be accomodated to a maximum level
7.	What-if capacity	Integer	5	Used when the user does a what-if analysis in the system. The value of this field will be lesser than the maximum capacity
8.	operating cost	Integer	10	Indicates the current operating cost of the depot
9.	salvage cost	Integer	10	Represents the salvage cost of the depot in case of a closure
10.	fixed cost	Integer	10	This field stores the fixed cost for the depot

Exhibit 6: Terminus Table

Sl. No	Name	Type	Size	Description
1.	id	Integer	5	Id is generated by the database automatically as an auto increment field.
2.	Terminus code	Varchar	20	A unique terminus code assigned to each terminus is stored in this field
3.	Terminus name	Varchar	50	The name of the terminus which usually denotes the location of the terminus

Exhibit 7: Terminus-Depot Table

Sl. No	Name	Type	Size	Description
1.	id	Integer	5	Id is generated by the database automatically as an auto increment field.
2.	terminus code	Varchar	20	The terminus code in terminus table (refer Exhibit 2) is stored here as a foreign key
3.	depot code	Varchar	20	The depot code in depot table (refer Exhibit 1) is stored here as a foreign key
4.	distance	float	N/A	The distance between the terminus and the depot value is stored in this field

Exhibit 8 : Bus Table

Sl. No	Name	Type	Size	Description
1.	id	Integer	5	Id is generated by the database automatically as an auto increment field.
2.	route no	Varchar	10	A unique bus no (route no) is stored in this field. If there are multiple buses with the same number, the system automatically adds a sequence number followed by a "-" to make it unique
3.	depot code	Varchar	20	The depot code in depot table (refer Exhibit 1) is stored here as a foreign key
4.	terminus start	Varchar	20	The terminus code in terminus table (refer Exhibit 2) is stored here to indicate the starting terminus of the bus route.
5.	terminus end	Varchar	20	The terminus code in terminus table (refer Exhibit 2) is stored here to indicate the ending terminus of the bus route.
6.	fuel cost per km	Integer	2	The fuel cost per km for the corresponding bus is stored in this field. This is used to calculate the dead km.

Exhibit 9 : Result Table

Sl. No	Name	Type	Size	Description
1.	id	Integer	5	Id is generated by the database automatically as an auto increment field.
2.	depot code	Varchar	20	The depot code in depot table (refer Exhibit 1) is stored here as a foreign key
3.	route no	Varchar	10	A unique bus no (route no) is stored in this field.

Proposed Heuristic Method for LD-ABD problem

Step 1: Let 'Combination' = 0

Step 2: Select a combination of existing facilities [after considering closing facility (or facilities) combination] and new facility (or facilities) [after considering opening facility (or facilities) combination] . Combination = Combination + 1

Step 3: Compute Facilities Cost for the selected combination of existing facility and new facility

$$\textit{Facilities cost} = \begin{pmatrix} Fixedcostinvolved \\ inopeningofnewfacility \end{pmatrix} - \begin{pmatrix} Revenueobtainedfromclosing \\ theexistingfacility \end{pmatrix}$$

Step 4: Using the selected combination of existing and new facilities, allocation of buses to the given set of facilities (depots) is formulated as transportation problem. As Mathirajan et al (2010) empirically proved that the initial basic solution method by Vogel's Approximation Method (VAM) provides near optimal solution, VAM is used for allocation of buses to depots to optimize the total dead-kilometre cost.

Step 5: Compute the Overall Cost for location of depots and allocation of buses to depots for the selected combination of existing and new facility

$$Overall\ Cost\ (combination) = (Facilities\ Cost) + (Total\ Dead\ Kilometer\ Cost)$$

Step 6: Repeat Step 2 to Step 5 for each possible combinations of existing facilities [after considering closing facility (or facilities) combination] and new facility (or facilities) [after considering opening facility (or facilities) combination].

Step 7: List combination wise the Overall Cost obtained and allow the user to choose the best combination based on the minimum overall cost and decision maker's subjective decision on the combination of existing facilities [after considering closing facility (or facilities) combination] and new facility (or facilities) [after considering opening facility (or facilities) combination].

Step 8: Based on the decision maker's choice on combination of existing and new depots the detailed reports on (a) list of closing depots, (b) list of opening new depots, (c) depot wise the overall summary on number of buses allocated along with the overall cost, (d) allocation of buses to depots are generated.

What if Analysis: The web interface module provides an user interface to modify the depot capacity, add more buses, add more terminus which gives the user a learning processes of what happens to the result for a specific scenario/modification. After the data is updated, the heuristic module executes it with this option.

Module 5: Report Generation Module:

The report generation module generates various management reports. Accordingly this module generates the following reports:

- Bus Status Report (Exhibit 10):For each bus, the details about the start terminus, end terminus, existing depot allocation details (depot, distance and cost) and the efficient depot allocation details (depot, distance and cost) will be generated.
- Depot Bus Allocation Report (Exhibit 11):This report displays bus no, depot allocated by C-DSS, terminus details, fuel cost per km, dead kilometer cost, etc.
- Depot-wise change summary Report (Exhibit 12): This report provides the change summary for each depot by providing the details on which are the buses moved to which are the depots and the buses allocated to that depot from other depots.
- Summary Report (Exhibit 13): This report provides a summary at the depot level such as number of buses allocated, its dead km and cost, etc. These details are presented for both existing allocation and efficient allocation along with savings due to efficient allocation.

Testing, Verification and Validation of the Proposed C-DSS

Testing: As part of the testing process for the proposed C-DSS, the following standard testing strategies are carried out :

- Module Testing – Each module is tested independently to check whether the interfaces to the methods are working fine.

- Functional Testing – Each function written in the modules are tested independently and the functionality is tested using the simulated data.
- User Interface Testing – The web interface components are tested to make sure that the appropriate information is retrieved from the backend and also information is stored into the backend.
- System Testing – This testing makes sure that all the different modules along with the user interface works fine.

Verification: Verification of the proposed C-DSS is done by using numerical example, presented in Annexure 1, for ABD problem. The numerical example problem is solved manually and compared with the results generated by the proposed C-DSS.

Validation: Though the ideal validation of the proposed C-DSS needs to becarried out by solving large scale real life data, generated based on the observation made in Bangalore based URTO, in this paper the validation is carried out as follows by considering a numerical problem:

Exhibit 10 : Report 1- Bus Status Report

			Existing Allocation			Efficient Allocation		
Bus No	Start Terminus	End Terminus	Depot	Distance	Cost	Depot	Distance	Cost
R1	SBS	BBS	D1	18.5	203.5	D1	18.2	200.2
R2	CMT	CMT	D1	8	96	D3	8	96
R3	MBS	BBS	D1	17.3	190.3	D2	14.8	162.8
R4	GNR	SNR	D2	16.6	182.6	D2	9.4	103.4
R5	SNR	GNR	D2	16.6	199.2	D2	9.4	112.8
R6	GNR	GNR	D2	15.2	152	D2	8	80
R7	BBS	SBS	D2	18.5	222	D1	18.2	218.4
R8	CMT	BBS	D2	15	165	D1	15.2	167.2
R9	BBS	SBS	D2	18.5	222	D2	19	228
R10	CMT	BBS	D2	15	150	D3	15	150
R11	MBS	SBS	D3	13.8	151.8	D3	13.8	151.8
R12	MBS	MBS	D3	12.6	138.6	D2	11.6	127.6
R13	CMT	SBS	D3	11.5	138	D3	11.5	138
R14	SNR	BBS	D3	20	240	D2	14.4	172.8
R15	CMT	SBS	D3	11.5	115	D3	11.5	115

Exhibit 11 : Report 2: Depot Bus Allocation Report

Sl. No	Bus No	Depot by DSS	Start Terminus	Distance	End Terminus	Distance	Existing Depot	Fuel Cost	Dead Kilometer Cost
1	R8	D1	CMT	5	BBS	10.2	D2	11	167.2
2	R1	D1	SBS	8	BBS	10.2	D1	11	200.2
3	R7	D1	BBS	10.2	SBS	8	D2	12	218.4
4	R6	D2	GNR	4	GNR	4	D2	10	80
5	R5	D2	SNR	5.4	GNR	4	D2	12	112.8
6	R4	D2	GNR	4	SNR	5.4	D2	11	103.4
7	R12	D2	MBS	5.8	MBS	5.8	D3	11	127.6
8	R3	D2	MBS	5.8	BBS	9	D1	11	162.8
9	R14	D2	SNR	5.4	BBS	9	D3	12	172.8
10	R9	D2	BBS	9	SBS	10	D2	12	228
11	R2	D3	CMT	4	CMT	4	D1	12	96
12	R15	D3	CMT	4	SBS	7.5	D3	10	115
13	R11	D3	MBS	6.3	SBS	7.5	D3	11	151.8
14	R13	D3	CMT	4	SBS	7.5	D3	12	138
15	R10	D3	CMT	4	BBS	11	D2	10	150

Exhibit 12 : Report 3 : Depot wise Change Summary Report

Depot:D1 - Depot1

Route No	Start Terminus	End Terminus	To Depot	From Depot
R1	SBS	BBS	-	-
R2	CMT	CMT	D3	-
R3	MBS	BBS	D2	-
R8	CMT	BBS	-	D2
R7	BBS	SBS	-	D2

Exhibit 13 : Report 4: A Summary Report

Depot-wise summary details

		Existing Allocation			Efficient Allocation		
Depot Code	Depot Name	# buses	Dead kms	Cost	# buses	Dead kms	Cost
D1	Depot1	3	43.80	489.80	3	51.60	585.80
D2	Depot2	7	115.40	1292.80	7	86.60	987.40
D3	Depot3	5	69.40	783.40	5	59.80	650.80
Total		15	228.60	2566.00	15	198.00	2224.00

A Numerical Example for LD-ABD Problem: The numerical example for ABD problem presented in Annexure 1 is extended to capture the LD-ABD problem and the extended problem is presented in Annexure 2. The numeric example presented in Annexure 2 for LD-ABD problem is executed in the proposed C-DSS system and the result is shown in Exhibit 14 to obtain decision maker's choice for the scenario on the selection of existing facilities and new facilities. Based on the choice of the Decision Maker, the various reports are generated similar to the reports given in Exhibits 10 to 13.

Exhibit 14: Overall cost for the Selected Combination of Existing Depots and New Depots

Possible scenarios for LD-ABD problem

Scenario	Closing Depot	Opening Depot	Salvage Cost for closing depot	Fixed Cost for opening depot	Total Dead Km Cost	LD-ABD Cost for the scenario	Action
1	D1	D4,D5	180000	275000	2593	97593	Generate Reports
2	D1	D4,D6	180000	325000	2784	147784	Generate Reports
3	D1	D4,D7	180000	295000	2730	117730	Generate Reports
4	D1	D5,D6	180000	250000	2590	72590	Generate Reports
5	D1	D5,D7	180000	220000	2539	42539	Generate Reports
6	D1	D6,D7	180000	270000	2793	92793	Generate Reports
7	D3	D4,D5	200000	275000	2605	77605	Generate Reports
8	D3	D4,D6	200000	325000	2814	127814	Generate Reports
9	D3	D4,D7	200000	295000	2774	97774	Generate Reports
10	D3	D5,D6	200000	250000	2614	52614	Generate Reports
11	D3	D5,D7	200000	220000	2574	22574	Generate Reports
12	D3	D6,D7	200000	270000	2845	72845	Generate Reports

Note: The highlighted scenario in the Table is the relatively efficient solution provided by DSS.

CONCLUSION

The proposed C-DSS for ABD/LD-ABD problem is successfully validated on a small scale hypothetical problem. In addition, as this study is part of the output of ongoing research project, funded by Karnataka State Road Transport Corporation (KSRTC) through the Center for Infrastructure, Sustainable Transportation and Urban Planning (CiSTUP) of Indian Institute of Science (IISc), the researchers are under the process of collecting all the real life date related to ABD / LD-ABD decision problems of Bengaluru Metropolitan Transport Corporation (BMTC), Bangalore for the ideal validation of the proposed C-DSS.

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Annexure 1

A Numerical Example for Allocation of Buses to Depots (ABD) Problem

The objective of the numerical example problem given here is to minimize the total dead kilometer cost by optimally allocating the given N (= 15) number of buses to existing M (= 3) number of depots.

Existing Bus-Depot Allocation

Depot 1 : D1

Sl. No.	Route No.	Starting Terminus (ST)	Distance From ST to Depot	Ending Terminus (ET)	Distance From ET to Depot	Fuel Cost Per KM
1	R1	SBS	8.0	BBS	10.2	11
2	R2	CMT	5.0	CMT	5.0	12
3	R3	MBS	12.0	BBS	10.2	11

Depot 2 : D2

Sl. No.	Route No.	Starting Terminus (ST)	Distance From ST to Depot	Ending Terminus (ET)	Distance From ET to Depot	Fuel Cost Per KM
1	R4	GNR	4.0	SNR	5.4	11
2	R5	SNR	5.4	GNR	4.0	12
3	R6	GNR	4.0	GNR	4.0	10
4	R7	BBS	9.0	SBS	10.0	12
5	R8	CMT	7.0	BBS	9.0	11
6	R9	BBS	9.0	SBS	10.0	12
7	R10	CMT	7.0	BBS	9.0	10

Depot 3 : D3

Sl. No.	Route No.	Starting Terminus (ST)	Distance From ST to Depot	Ending Terminus (ET)	Distance From ET to Depot	Fuel Cost Per KM
1	R11	MBS	6.3	SBS	7.5	11
2	R12	MBS	6.3	MBS	6.3	11
3	R13	CMT	4.0	SBS	7.5	12
4	R14	SNR	9.0	BBS	11.0	12
5	R15	CMT	4.0	SBS	7.5	10

Distance between Starting/Ending Terminus and Depot#

Terminus Code	Terminus Name	Distance from 'Terminus' to the Depot		
		D1	D2	D3
BBS	Bangalore Bus Station	10.2	9.0	11.0
CMT	City Market	5.0	7.0	4.0
GNR	Gandhi Nagar	9.4	4.0	7.6
MBS	Malleswaram Bus Station	12.0	5.8	6.3
SBS	Shivajinagar Bus Station	8.0	10.0	7.5
SNR	Srinagar	5.0	5.4	9.0

This is a Crucial Input Data and generally this complete data is not be available in URTO in India [However this is possible to generate this data if GIS is used in URTO]

Annexure 2

A Numerical Example for Location of Depots and ABD (LD-ABD) problem

The numerical example for ABD problem presented in Annexure 1 is extended to capture the LD-ABD problem. For capturing the problem features of LD-ABD in the numerical problem, the following data are provided:

- Number of buses increased from 15 to 20 and the required data for these new additional buses is as follows:

Sl. No.	New Route No.	Starting Terminus (ST)	Ending Terminus (ET)	Fuel Cost Per KM
1	R16	BTL	BBS	10
2	R17	SBS	JPN	12
3	R18	CMT	BTL	10
4	R19	JPN	BBS	12
5	R20	BTL	JPN	11

- Possible to close 2 exiting depots with immediate requirement of closing only one depot. To capture this requirement, the depot wise salvage cost, which is due to closing the possible depot, is given as follows:

Sl. No.	Existing Depot Code	Existing Depot Name	Existing Depot Capacity	Possible Depot to Close	Salvage Cost due to Closing Depot
1.	D1	Depot 1	3	Yes	180000
2.	D2	Depot 2	7	No	0
3.	D3	Depot 3	5	Yes	200000

- Possible to open four new depots with immediate requirements of opening 2 new depots only. For addressing this specific requirement, the new depot wise name of the depot along with depot code, fixed cost, and capacity is given as follows:

Sl. No.	New Depot Code	New Depot Name	New Depot Capacity	Fixed Cost due to Opening Depot
1.	D4	Depot 4	10	175000
2.	D5	Depot 5	8	100000
3.	D6	Depot 6	10	150000
4.	D7	Depot 7	9	120000

- Due to increase in the number of buses with new terminus and a set possible new depots for LD-ABD problem, the date on *distance between (Existing and New) Starting/Ending Terminus and Depots (existing and New Depots) is required as follows:*

Terminus Code	Terminus Name	Distance from 'Terminus' to the Depot						
		D1	D2	D3	D4	D5	D6	D7
BBS	Bangalore Bus Station	10.2	9.0	11.0	8.5	7.0	9.0	11.0
CMT	City Market	5.0	7.0	4.0	6.0	5.0	5.4	4.0
GNR	Gandhi Nagar	9.4	4.0	7.6	8.0	6.5	8.5	7.0
MBS	Malleswaram Bus Station	12.0	5.8	6.3	8.5	6.5	7.5	8.0
SBS	Shivajinagar Bus Station	8.0	10.0	7.5	6.5	6.0	7.5	9.2
SNR	Srinagar	5.0	5.4	9.0	8.0	6.2	7.3	4.2
JPN	JP Nagar	9.0	10.0	6.0	7.5	8.5	8.0	5.7
BTL	BTM Layout	8.0	9.0	6.5	9.0	7.0	7.5	6.3

INNOVATIVE PROJECTS BY FRESHMEN ENGINEERING STUDENTS

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ABSTRACT

Innovation, entrepreneurship, and leadership are critical skills for engineering students. Practical innovative projects help students develop their portable skills. Portable skills are skills that can transfer from one occupation to another, and from school to work. Companies profit and grow through the development of innovative products and designs. Engineers are often the leaders of product development teams. For product development in industry, a structured plan may be used to encourage brainstorming and help enhance creativity.

Keywords – Projects, Innovation, Entrepreneurship, Leadership

Introduction

This paper outlines the process for teaching critical innovative skills in our class "Introduction to Engineering." The steps taught to develop innovative products are: idea generation, market research including stakeholder analysis, evaluation, product design and development, product protection, and commercialization. This paper also talks about leadership and entrepreneurship. Through the use of these steps and skills, we give students the tools to develop their innovation, entrepreneurship, and leadership skills.

Idea Generation

During the first week, the students are told how brainstorming is conducted in the lecture part of the class. Current students were also told about the products developed by previous students. They were also told that the best ideas were those that the students had a personal interest in developing, to fill an unmet niche. Once the list of potential products is developed, as in Table 1, students evaluate each product or concept, considering student interest in the project, strengths and weaknesses of the concept, feasibility of execution, etc. Students then form teams based on product interests, personal relationships, skills, or other factors. These teams will then work together to generate potentially marketable product concepts. Students must also be taught to keep an accurate log book and document their work carefully to protect their intellectual property rights.

Table 1: Brainstorming Innovative Products

PROJECTS	STUDENTS
1. Removable box handles	Henry, Menuwan
2. Frozen Lunch Box	Jovany, Brandon, AJ, Briana
3. Soap Filled Loofah	Brennen, Nick, Hunter
4. Electromagnetic Glove	Leonardo, Pam, Richard
5. Sensor Start	
6. Smoke Leak Detector	
7. Knife Sleeve	
8. Charger Home	
9. Laser Measure	
10. GPS Charging Device	

Market Research

Market research identifies customer needs and wants. This method can identify potential target groups or markets. Based on the target groups, students can identify the advertising techniques to reach each target group. Listening to customer requests for products and services is another way to develop or improve products and services. Market research can be used to determine geographic area of a business and/or demographics of customers (age, gender, income, etc.). Prospective customers have to be asked the right questions, and open-ended questions to get the best answers. If your product has competitors, you want to look at their weaknesses and develop a strategy to enter the market. Customer profiles will allow you to determine if the market is large enough and profitable enough to develop your product. During the second week, students will perform searches to make sure they are not duplicating products already on the market, as in Table 2. If they plan on developing an existing product they need to show how their product is better and/or different from the existing product.

Table 2: Research Selected Products

- **Removable Box Handles**
- Primary mode of research was through web browsing. Members involved in this project did their research and did not find any information that suggested our product had already been created. To further clarify we even accessed the current patents which confirmed that our product had not been created.
- Source: Topic, B. (n.d.). Retrieved September 10, 2016, from https://search.uspto.gov/search?query=removable box handles.
- We did manage to find a similar product with a different design.
- Source: Number, B. M. (n.d.). 3M Carrying Handles. Retrieved September 10, 2016, from http://www.uline.com/BL_6570/3M-Carrying-Handles?keywords=box handles
- Our primary objective is to create a product that can handle a heavy workload and is durable. The design of our product will include webbing straps, handles and locking mechanisms.
- Price of the webbing material planned to be used for our design will cost 0.38$ per foot.
- Source: Nylon Seat Belt Webbing 1" (n.d.). Retrieved September 10, 2016, from https://www.strapworks.com/Nylon_Seatbelt_Webbing_p/sbfnw1.htm
- The design of the handles and locking mechanisms will be made by this group and shall not be purchased.

Market research will let them know who their potential competition could be, and what would be an appropriate price range for the product. They should also consider demographic factors, establish timelines, and get a better estimate of the resources needed to complete their project. During the third week, the student groups make a timeline to guide the development of the product is shown in Table 3.

Table 3: Project Timeline for Removable Box Handles

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Brainstorming	X	X													
Research other Remote Pagers		X	X												
Team Task List			X												
Develop Survey				X	X										
Administer Survey						X	X								
Design		X	X	X	X	X	X	X	X						
Gather Materials									X	X	X				
Prototype										X	X	X	X		
Complete Report													X	X	
Presentation															X

During the fourth week students develop a survey consisting of various questions designed to retrieve feedback from possible consumers about the marketability of the product, as in Table 4. The survey also collects information about the consumers and is designed to help forecast possible

retail pricing and target populations. During week five, students compile the survey results as shown in Table 5.

Table 4: Survey Instrument for Electromagnetic Glove

Electromagnetic Glove Survey

- Based on the product described, how interested are you? (Circle one)
- Not Interested Slightly Interested Moderately interested Very Interested Extremely Interested
- What do, and don't, you like about this product? (Annotate below)
- What features would persuade you to purchase this product? (Can choose more than one)
- Price Functionality Design Popularity Other (please specify)
- Which functionality appeals to you? (Can choose more than one)
- On/Off function Magnetism Durable materials
- How likely are you to recommend this product to someone? (Circle one)
- Not Likely Somewhat Likely Moderately Likely Highly Likely Extremely Likely
- How much would you be willing to pay for this product? (Circle one)
- Under $10 $10-$19 $20-$29 $30-$39 $40-$49 $50+
- Are you in a career field or a hobbyist of auto repair or other types of maintenance? (Circle One)
- Yes No
- What suggestions do you have to improve this product? (Annotate below)
- **For the purpose of demographics, please answer the following questions:**
- Gender: Male Female Prefer not to answer
- Age: Under 18 19-25 26-35 36-45 46-55 56+ Prefer not to answer
- Income: Under $20,000 $20,000-$35,000 $35,000-$50,000 $50,000+ Prefer not to answer
- Do you have any suggestions that may improve the overall quality or effectiveness of this product?

Table 5: Survey Results

Survey Results for Electromagnetic Glove

- Based on the product described, how interested are you? (Circle one)
- Not Interested 30% Slightly Interested 0% Moderately interested 40% Very Interested 20% Extremely Interested 10%
- What do, and don't, you like about this product? (Annotate below)
- Like functionality but do not like that it doesn't have Iron Man capabilities
- Which functionality appeals to you? (Can choose more than one)
- On/Off function **20%** Magnetism **40%** Durable materials **40%**
- How likely are you to recommend this product to someone? (Circle one)
- Not Likely **0%** Somewhat Likely **40%** Moderately Likely **20%** Highly Likely **20%** Extremely Likely **20%**
- How much would you be willing to pay for this product? (Circle one)
- Under $10 **10%** $10-$19 **0%** $20-$29 **10%** $30-$39 **0%** $40-$49 **10%** $50+ **70%**
- Are you in a career field or a hobbyist of auto repair or other types of maintenance? (Circle One)
- Yes **40%** No **60%**
- What suggestions do you have to improve this product? (Annotate below)
- Add Iron Man capabilities, Make it strong enough to climb walls
- **For the purpose of demographics, please answer the following questions:**
- Gender: Male **40%** Female **20%** Prefer not to answer **40%**
- Age: Under 18 **0%** 19-25 **40%** 26-35 **20%** 36-45 **20%** 46-55 **10%** 56+ **0%** Prefer not to answer **10%**
- Income: Under $20,000 **0%** $20,000-$35,000 **20%** $35,000-$50,000 **10%** $50,000+ **70%** Prefer not to answer **0%**

Project Evaluation

Evaluation is the process of identifying and collecting information to help decision makers choose among available alternatives [1]. The words evaluation, assessment, and measurement are sometimes used interchangeably. Measurement is generally used for assessment or evaluation. Evaluation is done to determine value. Evaluation is a term more common with those engaged in research and development. Good evaluation utilizes measurement and observations, gathering evidence systematically, and analyzing the results objectively [2].

Once potentially feasible ideas have been generated and market analysis has been performed student teams must analyze their concepts according to some established criteria. The students then analyze the survey results during week six, to determine their target market as shown in Table 6. The evaluation criteria should include consideration of the product such as manufacturability, manufacturing costs, raw material availability, size, shape, material, color, price, projected sales volume, profitability, market strategy, adaptability to customer needs, and estimated cost of marketing. External factors to consider are market size, potential customers, competition, and demand. Internal factors include resources available, financial, equipment, time, and fit to program. In practice, this step is a filtering process in which only the ideas with greatest potential proceed.

Table 6: Survey Analysis

- **Electromagnetic Glove**
- It was discovered that the majority of the questioned population was moderately interested in the electromagnetic glove. Although, it was a close decision between that and not interested at all.
- There weren't many opinions or suggestions for the product but we were informed that it does need to include Iron Man capabilities as well as be strong enough to be able to climb walls.
- It was a pretty close vote at the top but it was surveyed that 40% of people were concerned with functionality and 30% with design when asked what features would most persuade them to purchase this product.
- The vast majority of the surveyed people were drawn to the magnetism as well as its durable materials and would also pay at least $50 for such a product.
- It was discovered that 40% of people would somewhat likely recommend this product to someone else.
- Although we received a large amount of consumer data, it was almost split down the middle of the group as to if they were a hobbyists or in the career field of maintenance or automotive repair, 60/40-yes/no.

Demographics:

- As far as the gender of the surveyed group goes, 40% were male but another 40% preferred not to answer such a question.
- It has also been determined that our target group is between the ages of 19 and 25 who makes $50,000 or more per year.

During week seven, the students develop a business plan (www. sba.org), as in Table 7. An extensive business plan would be required if the group wanted to apply for a bank loan. The Wi-

Fi student group found from their survey that customers were willing to pay up to $50 for their product. Some groups decided to price their product at the maximum the customers were willing to pay.

Table 7: Preliminary Business Plan

- **Soap Filled Loofah**
- **Description of Business:**
- The soap filled will be made of the material used for a regular loofah, but have a reasonable sized storage to hold the soap. Our bases behind the idea is to make a product that somebody would use in their daily life, but is a very reasonable and inexpensive to make.
- **Marketing:**
- The way we would get this out on the market and into the hands of the public would be by starting somewhere simple. For example, something like Facebook or Instagram, or any social media where we could advertise and not spend a penny to do it.
- If the product exploded and did well, we would then think about maybe doing a commercial or have it advertised on the internet by someone else.
- **Competition:**
- The only other competition in the market is just a regular loofah that is on the market now, and a bar of soap.
- **Personnel:**
- As a group we will advertise the product ourselves, manufacture the product, and distribute it as well.
- **Financial Data:**
- Looking at how much it would be to make this product, we are thinking it will be around $1 to $2 dollars. Through our survey, we came to the conclusion that the majority of the consumers would pay anywhere from $5 to $10 dollars for the product. So in conclusion if we were able to sell it for $5, we make more than double on the product.

Product Design And Development

Product development is a crucial phase in the product life cycle, because it is here that many ideas and choices come together to form one product. Product development covers design conceptualization to pre-production, to manufacture and distribution. Product development can be defined as the design and engineering required to make products serviceable, producible, and profitable [3]. User interviews can be used to generate ideas for new products. Gathering user needs information is also an essential part of the design process. Functional, expressive, and aesthetic factors are important [4]. Function needs may include variables such as fit and ease of use. Expressive needs address variables such as role or status in society. Aesthetic appearance for clothing includes durability, comfort, and fashion.

Constructing first prototype involves translating user needs and preferences into a visual model. The sketch and the specifications sheet contain information essential to the manufacturing process. Evaluating feasibility and planning production involves reviewing the prototype and

determining whether it should go forward into manufacturing. A variety of activities include evaluating the design, materials, specifications, and estimation of cost.

Manufacturability of a product includes potential market, engineering and production (quality and rate of production), and financial matters (optimizing cost). During production, reevaluation could take place based on user evaluations after review of product. Marketing refers to the promotion (advertising) and distribution to the consumer. It includes brand image and response to market changes. Appropriateness of end use is inferred from user initial needs input and from evaluation of finished product. User needs are determined from collecting information on limitations, problems, practical solutions, and style preferences. There is the constant search for affordable and cost-effective product.

Starting with week eight and until week 15, the students work on the details related to the design and development of a particular product. This will also satisfy ABET (Accreditation Board for Engineering and Technology) Criteria 2000 [5]. Developing product prototypes will require the use of discretionary funds to cover the cost of materials, parts, and equipment usage. Project based courses prompt for reflection and use of experience from learning activities in the coursework [6].

Product Protection

In order to promote wealth creation, nations have recognized ideas, creative works, and designs protected under intellectual property law. This temporary assignment of ownership over intellectual works meets the need of finding the balance between private interests in wealth accumulation and the public interest of the product eventually being introduced in the public domain.

Protection of products and intellectual properties by patenting or copywriting of new products are essential for long term survival and growth. However securing a patent can take up to two years and cost up to $10,000 in legal fees. Intellectual property policy protects the rights of all co-inventors. All participants must keep careful records of their activities in the form of engineering log books.

Commercialization

Once products have been conceived, selected, developed and protected, they must be successfully commercialized. Commercialization explains the actions and decisions required in

getting a product to a given market. Technological innovation must be transformed into commercially successful products and services that meet customer needs. Commercialization is the art of taking an invention or a technology and developing a product or service for either consumer or industry.

Entrepreneurship

Entrepreneurship increases people's standard of living through creation of new firms that generate value by selling new products and services [7]. Entrepreneurship can be defined as leadership that contributes to the pursuing of profit opportunities to fill currently unsatisfied needs or improve inefficiencies [8]. New venture creation can increase employment and lead to economic development. Entrepreneurial orientation is an individual's attitude towards engaging in entrepreneurial activities. Entrepreneurship is the introduction of a new good, the introduction of a new method or product, the opening of a new market, the conquest of a new source of supply of new materials and the carrying out of a new organization of any industry [9].

During week 8, students develop a table of start up costs as in table 8. Start up expenses will include the cost of obtaining the necessary business licenses, operating expense for the first three months, and any expenses needed to get the business up and running. Include your salary and taxes for the first year. The rule of three takes your desired yearly salary and multiplies it by three to obtain the total start up expenses. If you have a home business, this can be cut down to twice your salary. Remember that financing is difficult to get when you first start out. Your most common financing source will be your home equity and personal savings. You may be able to use your family members as a financing source. You must always remind them that there is a good chance that you may lose all of the money. Table 8 shows start up cost variables. You may be fortunate to get clients that will pay a small percentage up front as a down payment for your services. You may be able to pay for the expensive professional liability insurance on a quarterly basis.

During week 9 students develop an income statement, as in table 9. The income statement also goes by the name profit and loss statement. This statement is a snapshot of your monthly revenues and expenses. You can see how your company performs each month. Revenues are accounts receivable. This is what clients pay for your services/products. Outstanding invoices are not logged until the client pays them. The last part of the income statement is the subtraction of the expenses from the revenue. If this is positive, you have a net income. If it is negative, you have a net loss.

Since this is a monthly picture, some months may have a net loss, when there is not much income coming in. hopefully by the end of the year, there are more gains than losses.

Table 8: Startup costs – Remote Pager

	Cost
Advertising	$3,000
Business state licenses	$300
Computer equipment	$1,000
Office furniture	$500
Office supplies	$300
Professional liability insurance	$500
Professional organizations	$0
Rent	$0
Three months of pay	$8,000
Web development	$300
Other expenses	$500
Total start up expense	$14,400

Table 9: Pro Forma Profit/Loss Statement – Electromagnetic Glove

Sales Revenues	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$600,000
Gross Profit Percentage	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	
GROSS PROFIT	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$420,000
Fixed Expenses													
Office rent	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$12,000
Salaries	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$150,000
Utilities	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$3,000
Telephone service	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$1,200
Office supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Postage	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$30,000
Website hosting	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$3,000
Insurance	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$6,000
Professional services (accountant, etc.)	$0	$1,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,000
<enter other fixed cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0
<enter other fixed cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0
<enter other fixed cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0
Miscellaneous	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL FIXED EXPENSES	$17,100	$18,100	$17,100	$17,100	$17,100	$17,100	$17,100	$17,100	$17,100	$17,100	$17,100	$17,100	$206,200
NET PROFIT (LOSS)	**$17,900**	**$16,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$17,900**	**$213,800**

During week 10 students develop a cash flow statement, as in table 10. This is a good planning document. This statement estimates how much money flows in and out of your business during a specific period. The cash flow statement reflects when your company expects to receive income, and when the company expects to pay bills. This is an extremely valuable tool to ensure that your company will have cash on hand to pay for its obligations. You can do cash flow statements quarterly.

Table 10: Pro Forma Cash Flow Statement – Electromagnetic Glove

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Cash at Beginning of Month	$0	$27,300	$43,000	$59,700	$76,400	$93,100	$109,800	$126,500	$143,200	$159,900	$176,600	$193,300
Cash Ins												
Sales Paid	$0	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
Loans & Transfers	$75,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL CASH INS	$75,000	$77,300	$93,000	$109,700	$126,400	$143,100	$159,800	$176,500	$193,200	$209,900	$226,600	$243,300
Cash Outs												
Start-up costs	$14,400											
Inventory	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000
Office rent	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Salaries	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500	$12,500
Utilities	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250
Telephone service	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100
Office supplies	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Postage	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Website hosting	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250
Insurance	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500
Credit card payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Loan payment	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200
Professional services (accountant, etc.)	$0	$1,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
<enter other cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
<enter other cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
<enter other cost>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Miscellaneous	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL CASH OUTS	$47,700	$34,300	$33,300	$33,300	$33,300	$33,300	$33,300	$33,300	$33,300	$33,300	$33,300	$33,300
CASH AT END OF MONTH	**$27,300**	**$43,000**	**$59,700**	**$76,400**	**$93,100**	**$109,800**	**$126,500**	**$143,200**	**$159,900**	**$176,600**	**$193,300**	**$210,000**

During week 11 students develop parts of a business plan: Introduction, industry overview, products & processes, marketing, operating plan, and financial plan. The introduction gives a brief overview of the company's purpose and financial summary. The industry and its current status are reviewed and its products and processes are described. The marketing plan consists of a market analysis, marketing survey, marketing strategies, and sales forecasts. The operating plan describes the company's location, employees, raw material, and production. The financial plan includes financial statements, the capital requirements, and an economic analysis.

During week 12, students complete the executive summary. The executive summary should be a clear, concise summary and should be able to stand alone. Some of the topics discussed are the type of business, services provided, form of ownership, the company's principles, how much money is required, and the utilization of the money. The executive summary is the first section of the business plan, but is written last. The section also includes the company's objective and mission statement.

During week 13 students complete the business plan (10 to 40 pages). This should include: 1. Cover sheet that includes company name, address, and phone & email. 2. Executive summary. 3. Company description (structure, ownership, location, business, growth of company, industry). 4.

Company services. 5. Market analysis (competition). 6. Financial analysis (income, cash, flow, and balance sheet).

The company description section should include the company's structure, ownership, and other basic information such as location. Even though this section seems obvious to the owner, remember the target audience for the business plan is investors and/or lenders. With this in mind, include a brief description of the business industry that your company is in to help lenders know what your company does. Also include the current economic health of your company, and the projected growth of the company and industry.

Your company service includes details of the services you will be providing. You want to research these services to include competitive pricing. Your prices will ultimately depend on what your client is willing to pay. Explain any unique advantage your company has over your competitors, and explain why your client needs to choose your firm over the competition. If you can identify ways to capitalize on your competition's mistakes, your company will benefit. By finding unique market nitches, your company can survive and thrive.

Market analysis includes understanding the market and finding opportunities in the marketplace. It is the best way for your company to grow and thrive. Find your market niche, based on your experiences and expertise. Use the internet for your research. If you have expertise in your field, then you know your targeted clients. If you do not, then research will help you find your targeted clients. Once you know your clients, you have to know your competition. You need to pick the competition that is your size, and has your capabilities, so that you can compete with them. Bigger firms will have capabilities that you do not possess, so it will be difficult to compete with them. You also have to know the business environment for your market area, as its health and vitality will affect your clients and their needs, and thus your company.

The financial analysis will help you project your company's revenue, financial state, and future financial goals. The first step is to forecast your company's sales for the first year, and then for the first five years. This will require you to figure out what you are going to do, how much can you make/complete in a given time, and how much can you price your product/service as shown in Table 9. During week 14 and 15, students complete a presentation of the business plan (10 to 20 slides). This should be a comprehensive presentation of the paper done in week 13.

Leadership

Leadership is the demonstrated ability to set goals, get commitment, and build capability. A leader is someone who leads an organization strategically in alignment with the organization's goals, so that it is successful. Leaders influence others (followers). Leadership traits may include extreme intelligence, good memory, persuasiveness, and unlimited amount of energy. Leaders care about their followers. Production oriented behaviors involve completion of tasks. Employee oriented behaviors include skills and relationships with their employees.

In both the public and private sector leadership is perceived as a critical requirement for organizational success. We need people who are willing to take a risk, to innovate, and to create a new way of thinking. Leaders of tomorrow will have to help people see the possibilities that exist beyond what they know today. Leadership is the behavior of an individual when he/she is directing the activities of a group towards a shared goal [10]. True leadership is leaders and followers working together to achieve mutual goals [11]. Leadership requires the ability to understand and deal with complexity, long time horizon, integrative skills, system design skills, and conceptual ability [12]. Traits such as drive, the desire to lead, honesty, integrity, self confidence, cognitive ability and knowledge of the business make it more likely that a leader will be successful. By formulating a vision, role modeling, and setting goals, a leader can use his or her talents to build a successful organization. The purpose of leadership is to enable all organizational members to choose to move in a common direction and accomplish the organizational tasks successfully [13].

Coopetition is the simultaneous pursuit of collaboration and competition to generate competitive advantage [14]. Competition is particularly important in high-tech industries where products have short life cycles and massive R&D costs [15].

During week 16 students can explain the leadership structure of their business. They can also explain the strategy that the organization will follow, so that the employees know the core values and practices that will guide the business.

Conclusion

This paper outlined the process for teaching critical innovative skills in our class "Introduction to Engineering." The steps taught to develop innovative products are: idea generation, market research including stakeholder analysis, evaluation, product design and development, product protection, and commercialization. This paper also covered the topics of

leadership and entrepreneurship. Through the use of these steps and skills, we give our students the tools to develop their innovation, entrepreneurship, and leadership skills.

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CAMPUS-WIDE SUSTAINABILITY AT TEXAS A&M UNIVERSITY-COMMERCE: AN HONORS THESIS

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ABSTRACT

This research begins with a definition of sustainability and its three pillars: the economy, the environment, and the society. It shows examples of unsustainability and how unwise decisions negatively affect the three pillars of sustainability. Later, this research discusses the historical background of the sustainable development in higher education. It talks about challenges and obstacles that make it difficult to see the importance of campus sustainability and ways to overcome those challenges. Additionally, it provides examples of creative sustainability initiatives and activities held by some universities in the United States, their accomplishments, and benefits. Performance contracting companies like Johnson Controls work with universities to maximize the efficiencies and performance of the campus and improve their learning environment. Most importantly, the sustainability survey was conducted on Texas A&M University-Commerce (A&M-Commerce) campus in September 2016 as part of this research. The population sample of this survey consisted of students, faculty, and staff of A&M-Commerce. The purpose of the survey was to assess the respondent's knowledge of sustainability topics, their level of interest to contribute to sustainable development on campus, and in which areas of sustainability students, faculty, and staff thought A&M-Commerce was the strongest and the weakest. The survey results were analyzed and discussed, and conclusions were made accordingly.

Introduction

Sustainability is a word commonly used in academic writings today with topics ranging from waste management to energy to the environment. Before talking about sustainability, it is necessary to understand what sustainability is and why it is important. In particular, the question, "what is campus sustainability and how can our campus become more sustainable?" should be answered. In addition, it is necessary to discuss short and long-term benefits with respect to the world, nation, campus, and the individual.

Brundtland penned two inspiring definitions of sustainability in her famous report "Our Common Future" issued in 1987 by the World Commission on Environment and Development (WCED). The first definition is commonly used as a mission statement by different organizations: "Sustainable development is development that meets the needs of the present without

compromising the ability of future generations to meet their own needs" (Waas, Hugé, Verbruggen, & Wright, 2011, p. 1648). The second definition that appears less frequently is used as an operational definition of sustainability: "In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (Waas et al., 2011, p. 1649). There are three main pillars of sustainability: the economy, the society, and the environment. The largest pillar of the three is the environment. Without a healthy environment, the world cannot sustain itself. Humans rely on resources such as animals, plants, water, and minerals for food, energy, medicine, building materials, and for everything they do in society. Without these resources, society could not have an efficient economy. If any one of the three pillars is weak, the entire system is unsustainable (Moldan, Janoušková, & Hák, 2012).

It is impossible to make the world sustainable overnight. However, small steps can be taken in the right direction. Campus sustainability represents a much more achievable goal with a lasting impact. The importance of campus sustainability is that it carries a significant impact because of the sustainable education that is given to the future generations. These future generations will become the leaders championing sustainability wherever they go (McFarlane & Ogazon, 2011).

Sustainability affects the world in many different ways. For example, electronic waste or e-waste comes from old computers, cell phones, televisions, and other electronic appliances. While this kind of waste comprises a small percentage of total waste, it is particularly hazardous. Despite international laws, this waste is often shipped off to developing countries like Ghana and Nigeria. Here the waste causes lots of health issues including negatively affecting the development of young children who try to survive by scraping e-waste for copper and aluminum. Part of sustainability involves directing waste, energy, and water to the appropriate destinations. The example above is often caused by companies claiming to recycle e-waste. In addition to e-waste, trees are cut at a much faster rate than they are able to reproduce and oil is extracted in large amounts to accommodate the increasing demand for natural gas and fuel. Other examples of harmful effects include the great amount of fresh water utilized in order to make beverages such as Coca-Cola, the tons of clean water used in the oil extraction process, etc. Education in the field of sustainability helps make steps toward a safer and more sustainable world (Nnorom & Osibanjo, 2008).

In addition to the environmental benefits of sustainability, various economic benefits can be listed. A report from Texas A&M University in 2012 reveals significant savings as a result of sustainable focus:

> In the last nine years (from FY2002 through FY2011), energy consumption at TAMU has dropped 22%, while the gross square footage served has increased by 21%. This translates into a 36% reduction in energy consumption per square foot. This significant drop in energy consumption has saved the university $120 million over the past nine years. ("Texas A&M University," 2012, p. 8)

Texas A&M University saved over $13 million a year through only energy conservation. TAMU has a total of 23 million square feet of floor space; whereas, Texas A&M University-Commerce (A&M-Commerce) has about 2.3 million square feet. Based on this data, A&M-Commerce could potentially save $12 million in the 9 year period, which is equivalent to about $1.3 million per year if A&M-Commerce sets a goal on an energy efficiency program similar to TAMU.

Literature Review

Concern for sustainability started in the early 1970s when people began to realize that economic development and societal prosperity depend on the environmental conditions. With the growing population, increasing technology, and the prioritization of economic growth, society's behavior put the environment at risk. This, in turn, increased the need for sustainability to be a crucial focus in the continuous development of society and economy, thus causing individuals to assess and revise their values.

The Stockholm Declaration of 1972 became one of the first documents published to give reference to the importance of sustainability in higher education and introduced some ways of achieving environmental sustainability. In 1990, Jean Mayer, the President of Tufts University, gathered 22 university leaders in Talloires, France to define the importance of sustainability in higher education. This event lead to the Talloires Declaration, "a 10-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities" (Alshuwaikhat & Abubakar, 2008, p. 1777). Three hundred university administrators in over 40 countries had signed the Declaration (Alshuwaikhat & Abubakar, 2008).

In 1992, Earth Summit introduced a sustainability action plan and called it Agenda 21. This plan highlighted human population, consumption, and technology as the major factors of environmental change (Kates, Parris, & Leiserowitz, 2005). Agenda 21 argues against wasteful and inefficient use of resources in some parts of the world while encouraging increased yet sustainable development in others. In addition, Agenda 21 stated that "education is critical for promoting sustainable development and improving the capacity of all people to address environment and development issues" (Clugston & Calder, 1999, p. 2). Campus-wide sustainability is the action plan all universities around the world should focus on in order to help reduce ecological degradation and preserve nature's essential resources for future generations.

The Princeton Review (2014) conducted a survey in which 2000 U.S. high schools participated. As a result, The Princeton Review created a list of 332 colleges that have developed sustainability programs and have a strong commitment to good stewardship of the environment. This number of colleges continues to grow each year. High school students get a chance to go through this list of colleges and universities and can choose which college they would like to go to based on their accomplishments in campus wide sustainability (The Princeton Review, 2014).

An article by Attaran and Gokhan (2014) discusses results of the survey conducted by The Princeton Review that show that the majority of high school students and their parents put significant importance to the school's commitment to the environment when choosing a college to attend. In the same survey, students reported that they would rather live and study on a campus that is more sustainable. In addition, this survey asked participants which area of sustainability that they consider most crucial and what additional percentage of their school tuition they would be willing to pay for improvements in the area they chose. The results showed that students are willing to pay an average of 3.71% of their tuition to contribute to the sustainability of their campus in five areas: Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), and Indoor Environmental Quality (EQ). Out of these five areas students were willing to pay the highest percentage of their tuition for improvements in the EA category. In summary, "EA focuses on efficient energy use by means of on-campus renewable energy and reducing ozone depletion while minimizing direct contribution to global warming" (Attaran & Gokhan, 2014, p. 688).

There are many sustainability approaches universities can take in order to become a part of national and worldwide sustainability programs. However, it is not an easy task for several reasons.

First, many university presidents and top administrators fear sustainability might negatively affect their institution's performance. This negativity is generally rooted in the distrust or fear of something new. Researchers agree that when this negativity is eliminated and the president and top administrators set their goals on supporting sustainability, this task gains a greater potential to prosper at these institutions (Thompson & Green, 2005).

Second, sustainability development is a long-term process that can take 20 to 40 years to fully establish on a campus. Because presidents serve a shorter term, they tend to focus mainly on short-term goals. Also, presidents and top administrators are focused on projects needing immediate attention, and sustainability is usually not one of them (Thompson & Green, 2005).

Third, sustainability can seem very costly at first, especially when there is a need for constructing new sustainable buildings, facilities, and power plants that generate electricity from renewable sources. Usually university administrators only see the costly side of the project without taking into consideration the long-term savings and benefits (Thompson & Green, 2005).

Next, Thompson and Green (2005) discuss obstacles that make it difficult to see the importance of campus sustainability. The first obstacle to participation in campus sustainability may be due to the inability of campus community to recognize or accept environmental degradation on campus that happens overtime. Creative presentation of such information might possibly make the campus community aware of the importance of campus sustainability (Thompson & Green, 2005).

The second obstacle is that people have become witnesses of faulty cultural models that seem to make sense of the world. "For example, most Americans have learned that a healthy campus landscape should include broad expanses of irrigated, chemically treated, low diversity turf. These landscapes, however, can harm the environment in many ways" (Thompson & Green, 2005, p. 11). For example, the chemicals used to treat turf contaminate storm water which goes down the storm drains; this process harms water organisms that serve important ecosystem functions such as filtering water. Additionally, in 1987 the National Cancer Institute studied the impact of lawn pesticides on human health. The results revealed that children who lived and played around chemically treated lawns were 6.5 times more likely to develop leukemia (Pineo & Barton, 2010). There are many other examples of everyday practices that people might think are beneficial for the environment which in turn are harmful. Therefore, it is necessary to educate the campus

community about the faulty cultural models, their impact on the environment, and suggest revised cultural models that are aimed toward campus sustainability (Thompson & Green, 2005).

The third obstacle is misperception and misinformation. People have trouble believing what they cannot see. This may be a reason for not taking action. Therefore, any on campus problem presented to the campus community should be visible and impactful to draw attention (Thompson & Green, 2005).

The fourth obstacle is limited time and resources. Faculty, students, and staff might not participate in sustainability-focused activities because they already have a considerable workload and limited time. In order to overcome this obstacle proponents of sustainability should create multiple opportunities with varying time commitments. In this way, students, faculty, and staff will have a chance to devote time to sustainability-focused activities as their schedule allows them to do so (Thompson & Green, 2005).

The fifth obstacle is pushing sustainability onto university's action agenda. Sustainability supporters must look for opportunity windows when they open. "Opportunity windows are time limited opportunities to make changes in the action agenda of an organization" (Thompson & Green, 2005, p. 13). For example, during major construction projects, a facilities director is employed, a curriculum is revised or developed, contracts are negotiated, and so on (Thompson & Green, 2005).

The sixth obstacle is the sites of unconventional wisdom. According to Van Der Ryn and Cowan (1996), "most of the contemporary built environment is the product of dumb design" (Thompson & Green, 2005, p. 14). Instead of keeping the ecology in mind when creating designs, people usually build campuses as they have been built in the past. A great way of presenting the damages of conventional ways we build campuses can be accomplished by creating demonstration sites. Showing an example of a sustainable construction verses unsustainable might encourage college communities to revisit their views on campus sustainability and motivate them to take action (Thompson & Green, 2005).

It is easy to get discouraged about campus sustainability when top administrators are not supportive enough. This usually happens because top administrators have overwhelming responsibilities. Therefore, it is necessary to focus on motivating faculty, students, and staff using creative ways of engaging them into sustainable development of their higher institution (Thompson & Green, 2005).

One of the best ways to save money and help the environment is to make efficient use of the electricity provided. Not only does it help reduce the carbon footprint of the school, but it also helps to save a significant amount on the energy bill. According to The Princeton Review, Austin College initiates the UnPlugged competition, which encourages hundreds of undergraduate students to conserve electricity and compete between residence halls (The Princeton Review, 2014).

Based on the Texas A&M University Division of Administration Office of Sustainability's Biennial Report (2012), through the Energy Action Plan, which cost the University $15 million, TAMU replaced regular light bulbs with lighting retrofits in all facilities and parking lots. Also, 325 watt metal halide lamps got replaced with 400 watt high pressure sodium lamps. This upgrade is projected to reduce energy use by about 21%. Every year, TAMU also organizes competitions among residence halls. Utilities and Energy Management Master Plan accomplished a high level of efficiency by putting new chillers in the place of the old ones, by installing a very efficient Combined Heat and Power Plant, and by optimizing power plants as part of a plant optimization program. By implementing the Energy Action Plan, TAMU has reduced energy consumption per gross square foot (GSF) by 45%, which saved the University around $162 million over 11 years (Texas A&M University, 2014).

The University of Texas at Arlington (UTA) invested $27.9 million in building retrofits, upgrading systems, equipment, and energy controls. Their new facilities enabled them to save over $2.25 million a year with a simple payback of only eight years for a total saving of $18 million and continues to increase. UT Arlington partnered with Siemens Building Technologies (Siemens) which opened more opportunities to reduce energy consumption as well as emission of Green House Gases (GHG). This initiative focuses on HVAC (heating, ventilation, and air conditioning) improvements (Institute for Sustainability and Global Impact [ISGI] & UTA, n.d.).

In October 2009, Stanford committed to a long-term goal called "Energy and Climate Action plan." The plan focused on construction and expansion of high efficiency buildings, continuing to improve efficiency for existing buildings, and implementing the Stanford Energy System Innovations (SESI) project, an innovative energy supply system (Sustainable Stanford [SS] & SU, n.d.). Stanford invested $438 million for this project. It transformed from "gas fired combined heat and power with steam distribution to electrically powered combined heat and cooling with hot water distribution" (SS & SU n.d., p. 1). This system is expected to be 52% more

efficient than the existing system which used natural gas. In addition to that, SESI is projected to reduce Stanford's GHG emission by 68%, save 18% of Stanford's drinking water supply on top of the 21% reduction they have achieved in the last 15 years, and save $300 million over the next 35 years (SS & SU, n.d.).

Emory University in Atlanta held an event to encourage awareness of energy conservation where the main campus buildings went dark for half-an-hour. Emory's alumni around the world also participated by turning their lights out for half-an-hour (Deval, Murray, & Bowles, 2008).The University of Ohio has been saving 15.15 million kilowatt hours and 15,000 tons of CO2 since the installment of a "Computer Management Software that shuts down computers when they are not in use" (Deval et al., 2008, p. 4).

Tufts University in Massachusetts installed "vending misers" on 90 vending machines which turn off a vending machine's lights and cycling system when it is not being used. This saves the university about $17,000 and 100 tons of CO2 annually. Moreover, Tufts University saves an additional $23,000 and 17,000 gallons of water by using front-loader washing machines which also reduce CO2 emissions by more than 30 tons annually (Deval et al., 2008). Brandeis University in Massachusetts put stickers on their laundry machines encouraging students to use the "Bright Colors" or "Cold" water selection when doing laundry, as well as air drying their clothes (Deval et al., 2008).The State University of New York at Buffalo introduced a rule to keep university facilities at "68 degrees during regular occupied hours and 55 degrees during off-hours" (Deval et al., 2008, p. 5).

College Students' Perceptions of Campus Sustainability

Emanuel and Adams (2011) looked into "College students' perceptions of campus sustainability." This study was inspired by the 2007 Wingfield and Marcus report on "America's Greenest States." The states were rated according to energy consumption, air quality, carbon footprint, policy initiatives, and hazardous waste management. As a result Vermont was rated as the "greenest" state while West Virginia was the least green state. Hawaii rated 4th while Alabama rated 48th. This finding leads researches to this question: "Do Alabama college students' perceptions of campus sustainability differ from those of college students in Hawaii?" (Emanuel & Adams, 2011, p. 82).

In order to find an answer to this question Emanuel and Adams (2011) conducted a survey that was structured around students concern about the present/future, their knowledge about sustainability, and responsibility for sustainability (p. 83).

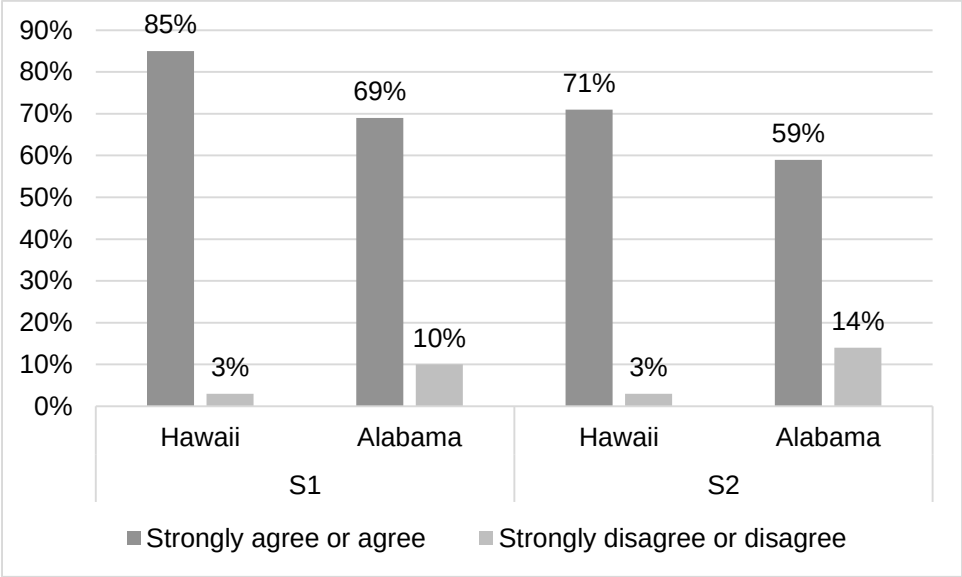

Figure 1. Concern for the present/future. Figure 1 shows the difference in responses between Hawaiian and Alabamian students of how concerned about the present/future they are as it pertains to sustainability. There is a slight difference in their responses but it is not very significant (Emanuel and Adams, 2011). S1: "I am quite concerned about the wasteful consumption of natural resources and the destruction/pollution of the environment". S2: "Our present economy is based on practices that will have negative consequences on the world's future generations" (Emanuel & Adams, 2011, p. 85).

In the same survey students were asked to identify one term that did not relate to sustainability among the other four that did. A greater percentage of Hawaiian students (70.1%) than Alabamian students (53.9%) gave the right answer. In the next question students were asked to identify one term that did relate to sustainability among the other four that did not. And again, a greater percentage of Hawaiian students (77.7%) than Alabamian students (55.4%) gave the right answer (Emanuel & Adams, 2011). The survey questions structured around students' contribution to sustainable development revealed that a higher proportion of Hawaiian students than Alabamian students make everyday life choices that are aimed towards sustainability (Emanuel & Adams, 2011).

In conclusion, college students in both the state of Alabama and Hawaii "know about the sustainability" and "who is responsible" but more Hawaiian students are "committed to get involved/contribute" to sustainability on campus even though majority students in Hawaii live off campus (Emanuel & Adams, 2011).

The authors of the study explain that student sustainability practices are somewhat dependent on the practices of their surrounding community. Hence, it does not matter whether the student stays on- or off-campus, their sustainable practices and knowledge come from the actions taken by the local community.

"Rather than wait for off-campus initiatives, college administrators must talk about, commit to, and lead the way in establishing sustainable practices on campus. They should provide opportunities and incentive to students, faculty and staff to engage in campus sustainability" (Emanuel & Adams, 2011, p. 90).

Universities and colleges in the United States and around the world are taking steps towards environmental protection and innovations in sustainable development. Providing opportunities and encouragement to students, faculty, and staff has great potential in leading the way towards a more sustainable future (Emanuel & Adams, 2011).

Performance Contracting

Energy Service Companies (ESCOs) around the world are working towards creating efficient environments. The ESCO industry, comprised of large, regional, and even smaller local companies, is very competitive. These companies are aimed at improving efficiency of governmental and business buildings by retrofitting entire buildings and upgrading water utilities. Such improvements help businesses and governments save money and reduce carbon emissions. Additionally, more efficient buildings are more comfortable, safe, and most importantly improve health of the people living and working in those buildings (Davis, 2013).

Johnson Controls

In 2004, Johnson Controls signed a 10-year performance contract worth $40 million at the University of Massachusetts. Johnson Controls (JC) conducted a detailed audit that helped them find opportunities for energy conservation. Improvements included adding electric cogeneration at the power plant, also known as combined heat and power (CHP), "installing electrical infrastructure upgrades, adding variable speed drives to motors, and upgrading fume hoods" (Davis, 2013, p. 3). In addition to that, JC installed chillers with higher energy efficiency, replaced steam lines, made lighting retrofits and implemented necessary measures to conserve water on campus. The University of Massachusetts invested $40 million in energy savings projects while saving $54 million in energy and operations over the 10-year contract period. Furthermore, the implemented improvements reduced maintenance backlog, improved the learning environment for

students and staff, and saved significant amount of money which opened the opportunity for the university to invest in other projects (Davis, 2013).

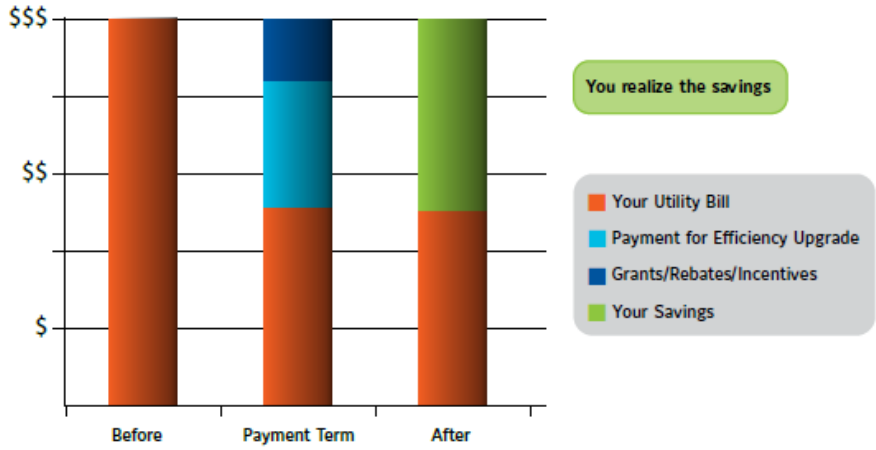

Figure 2. Energy Savings. This figure shows projects leveraging grants, incentives and performance contracting lead to significantly higher energy savings.

The Johnson Controls assurance specialist continued to work with the University of Massachusetts during the 10-year contract. The specialist's main job was to measure and verify energy savings. Johnson Controls also offers training classes in energy conservation, and supports and encourages on-campus energy conservation contests to educate students, faculty, and staff about the significance of the environment and economy in energy and water conservation (Davis, 2013).

Looking briefly at other schools examples is great, but what does that mean for Texas A&M University-Commerce (A&M-Commerce)?

Johnson Controls performed a Preliminary Energy Analysis (PEA) for A&M-Commerce during the spring semester of 2016. They offered a wide variety of Facility Improvement Measures (FIMs) in order to meet A&M-Commerce's energy and operational goals. Johnson Controls proposed a 26-year payback project. Their findings indicate that A&M-Commerce campus could save money in seven areas: controls and lighting system upgrades, solar window film application, integration of event management system (EMS) with the building automation system (BAS), mechanical upgrades, and central plant optimization. Additionally, they proposed installing Utility Sub-Meters that will allow the University to monitor consumption. The Sub-Meters will provide detail of actual consumption of areas for accounting purposes, and it will also help identify and target inefficient buildings. The proposed energy conservation measures, their total cost, annual utility savings and a payback period are presented in Table 1 (Johnson Controls, 2015).

Table 1
Proposed Energy Conservation Measures for A&M-Commerce

Improvement Measures	Cost ($)	Annual Utility Savings ($)	Simple Payback (Years)
Utility Sub-Meters	913,832	-	-
Controls Upgrades	4,697,212	152,063	30.9
Lighting Upgrades	3,035,171	174,080	17.4
EMS to BAS Integration	39,591	1,077	36.8
Solar Window Film	1,772,826	172,548	10.3
Student Housing Controls	1,053,929	61,667	17.1
Mechanical Upgrades	3,807,694	26,544	143.4
Project Total	15,320,255	587,979	26.1

Methodology

The ultimate goal of conducting a survey at A&M-Commerce was to find out what the university population knows about sustainability, their interest in learning about sustainability, and whether the University students, faculty, and staff are willing to contribute to the sustainable development of Texas A&M University-Commerce. The survey questions were taken from a similar study conducted in 2011 by the Grand Valley State University (GVSU) located in Allendale, Michigan (GVSU & Sustainable Community Development Initiative [SCDI], 2011). GVSU focused to assess sustainability literacy among their students. The survey assessed students' knowledge of sustainability topics, their level of interest to contribute to sustainable development on campus, and to find out in which areas of sustainability students thought GVSU was the strongest and the weakest. They conducted the same survey in 2009 and wanted to compare the results (GVSU & SCDI, 2011). My survey focused on finding similar results at A&M-Commerce except that it is not possible to compare the results with previous years since this was the first time the survey had been conducted. A comparison would be possible in a few years. The survey at A&M-Commerce was targeted to provide answers to the following questions:

1) How much does A&M-Commerce population already know about sustainable development? (Questions: 2, 3, 4, 12, 13)
2) Is there interest among A&M-Commerce faculty, staff, and students in contributing to sustainable development and do they feel responsible to change their behavior as it affects campus sustainability? (Questions: 5, 6, 7, 8, 9, 10)

3) What role does A&M-Commerce play in encouraging campus sustainability? (Questions: 11, 14, 18, 19)
4) Is the A&M-Commerce population interested in learning about sustainable development? (Questions: 15, 16, 17)

Population

The population sample of this survey included students, faculty, and staff of A&M-Commerce. Initially, 428 people attempted to take the survey but only 291 respondents finished the survey, which is 68% of 428 people who attempted. Most respondents were undergraduate students (69.31%), then staff (12.76%), faculty (11.38%), graduate students (4.83%), and (1.72%) of those who were both a student and a faculty member or a student and a staff member. Most participants (70%) were between ages 18-24, (11%) were between ages 25-34, (6%) were between ages 35-44 and 45-54, and finally (7%) were over 55 years old. Seventy percent of the respondents lived on-campus, and (30%) lived off-campus.

Procedure

The survey was conducted in September 2016 at A&M-Commerce. It was created on the Qualtrics website and distributed by e-mail to A&M-Commerce faculty, students, and staff. The survey duration was approximately between 10-15 minutes. It was available from September 12, 2016 to October 9, 2016.

Results

The results of the survey were analyzed by descriptive statistics and statistical inference for different groups. As part of the statistical analysis two-sample t-tests were used to compare the differences in several responses of two groups: faculty and staff (n = 69) as the first group, and students (n = 215) as the second group. Additionally, the researcher compared the responses of the survey participants from STEM (n = 68) and non-STEM (n = 222). A 95% confidence interval was used. The results to different set of questions in the survey are discussed below.

Knowledge about sustainability

When a question about having heard the term “sustainability” before was asked, half (51.89%) of the respondents said that they had heard the term before, (30.24%) said they had not heard the term before, and (17.87%) were not sure. Most of the respondents who heard the term

claimed to have heard it from faculty (43.90%), then signs and advertisements (24.39%), social media (19.86%), and friends (16.38%).

Having heard the term "sustainability" before is a good thing but what is more important is how much do students, staff, and faculty of A&M-Commerce actually know what it means and how it applies to their everyday life at the University. The next set of questions will help to understand it.

Attitude towards sustainability

Based on the answers of Question 5, the majority of students, faculty, and staff of A&M-Commerce are moderately to very concerned about issues like waste, safety and security, unemployment, energy use, water use, food waste, education, health and wellness, local business, and local economy as they pertain to sustainability. Out of these nine issues, the respondents were the least concerned about unemployment, local business, and local economy which belong to the economic pillar of sustainability.

Even though University students, faculty, and staff feel quite concerned about sustainability issues in Question 6, they indicated that their personal effort has little to do with influencing sustainability issues. This opens an opportunity to educate the University population about the significance of their personal effort with respect to change. Once the University students, faculty, and staff understand this concept, this can eventually lead to more people trying to bring positive changes to sustainable development on A&M-Commerce campus. This is a small step towards campus-wide sustainability that may bring big positive changes.

There is an interesting misbalance going on in the responses in questions 7, 8, and 9. The respondents strongly to somewhat agree that they are responsible to help make a difference on environmental (waste, energy, water use) and social (safety and security, education, and health and wellness) issues; however, they feel somewhat to neutral responsibility about economic (unemployment and local business/local economy) issues. A two-sample t-test found no significant difference ($p > 0.05$) in responses between faculty and staff and students. Additionally, no significant difference ($p > 0.05$) was found in the responses of the survey participants from STEM and non-STEM colleges. All groups have similar sense of responsibility towards environmental, social, and economic issues. This might mean that students, faculty, and staff feel responsible and willing to help make a difference yet they do not feel their efforts are going to be significant when

it comes to economic issues. For example, here is a comment left by a student: “My opinion does not matter. Yall are going to do what yall want anyways”.

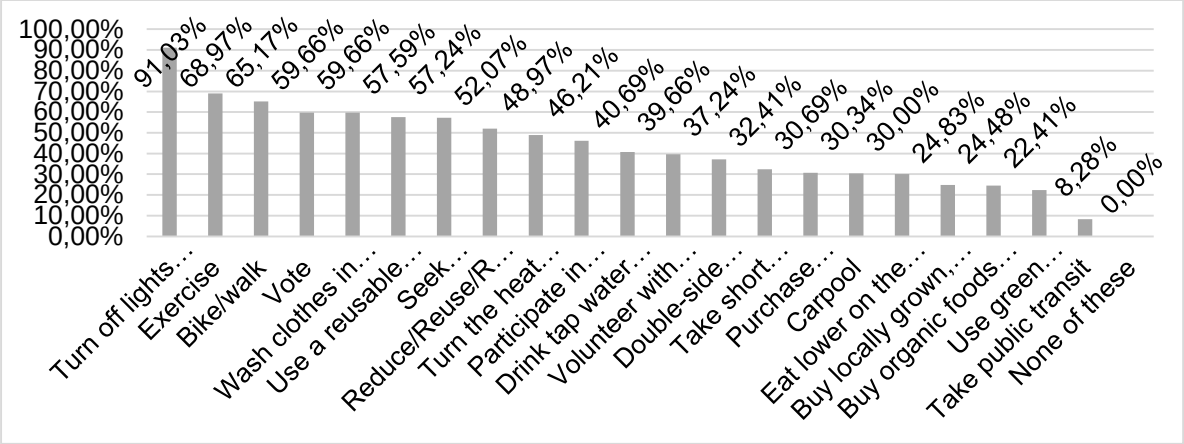

Figure 3. A&M-Commerce current lifestyle. The figure above represents basic sustainability practices taken by A&M-Commerce students, faculty and staff. The activities are sorted from largest to smallest percentage.

The role of A&M-Commerce in sustainability

Most respondents have heard of or currently participate in recycling activities, such as recycling plastic bottles and card board, on the A&M-Commerce campus. New students seem to be unaware of the few opportunities A&M-Commerce offers to promote sustainability. In question 11, few freshman students expressed their willingness to contribute and get involved in sustainable development activities but they do not know of any student organizations or groups they could become a part of. There are a few respondents who took personal effort in recycling despite not knowing of the existence of recycling opportunities on campus. This is very encouraging and inspiring. These are the people who bring about positive changes wherever they go in life.

The ultimate reason for creating open-ended questions like questions 11, 12, and 13 was to find out additional information not presented in this survey and to see how A&M-Commerce students, faculty, and staff rate their University involvement in sustainable development. As a result, most respondents gave neutral responses to questions 11, 12, and 13, like “N/A,” “NONE,” “IDK,” etc. Despite that, many respondents know about the recycling program on campus and some even make an effort to recycle and participate in this activity. Also, there was a number of comments from new students, staff, and faculty who are not aware of any sustainability-related activities but would love to participate if they were given the opportunity. Here are some interesting comments, “I (will) participate in all activities that relate to the items mentioned above.

I have been in Commerce for around 3 weeks only and I am willing to contribute to the community in terms of sustainability;" "I've heard of the recycling however I have also heard it is a show and they throw the recycling away;" "Our college has a recycling and environmental group and some of the organizations participate in giving back to the community by volunteering. We do highway clean up and habitat for the humanity. Also, some organizations adopt-a-highway or area."

Questions 12 and 13 asked students, faculty, and staff to identify in which areas of sustainability A&M-Commerce is the weakest and the strongest. The majority of respondents were not sure or did not know what to say. This confirms the weakness of sustainability knowledge at A&M-Commerce. This also means that there is an opportunity to fill the knowledge gap which can eventually help respondents answer questions 12 and 13. According to the respondents who were able to answer questions 12 and 13, A&M-Commerce is strongest in recycling and weakest in waste management of food, water, and energy resources. However, there was a significant number of respondents who believe that the A&M-Commerce recycling program could be further improved. In addition to that, respondents would like to see A&M-Commerce sustainability efforts focus on energy and water resources conservation, and elimination of food waste in the cafeteria. Here are some interesting comments: "I would like to see an actual recycling program across campus. It would also be really cool to keep the farmers market going, or bring it back to support locals;" "I would like to see the dining services donating extra food or possibly growing a garden full of veggies and fruits that students can purchase;" "Better tasting tap water if possible. More people would then use it;" "Encouragement of shopping at small business in the local area."

Results from question 18 show that, on the scale from 1 to 10, 53% of respondents gave a score above 5 to A&M-Commerce being supportive of sustainability. Question 19 shows even poorer results; 42% of respondents gave a score above 5 to A&M-Commerce for being successful at providing opportunities to be engaged in sustainability on the A&M-Commerce campus. Additionally, a two-sample t-test revealed that there was not a significant difference ($p > 0.05$) in the responses to questions 18 and 19 of the survey participants from STEM and non-STEM colleges. However, there was a significant difference ($p < 0.05$) in the responses of faculty and staff and students. Faculty and staff have higher expectations from A&M-Commerce in terms of being supportive of sustainable development on campus and providing opportunities to be engaged in sustainability. This may mean that faculty and staff know better than students what a sustainable campus looks like, having seen examples of successful sustainability programs and initiatives on

other university campuses. Based on their experience and knowledge, they realize that A&M-Commerce is considerably behind and has a lot of potential to improve its sustainability program on campus. It can be concluded that A&M-Commerce should set a goal on campus-wide sustainability and strive to be more supportive of sustainability related activities on campus to gain more respect and recognition from its faculty, staff, and students.

Interest in sustainability

The good news is that 52.76% of A&M-Commerce students, faculty, and staff are interested in learning about sustainability. This can be considered as a need that A&M-Commerce should strive to meet.

Thirty percent of respondents said they are "Not Sure" if they are interested in learning about sustainability. In my opinion, that means that these respondents do not know the importance of sustainable living today and its long-term benefits, its influence on the economy, society, environment, and well-being of future generations.

It is interesting to notice that 17.24% of respondents said that they are not interested in learning about sustainability. They might already know about sustainability and, therefore, most likely, know how to access information about it on campus. This assumption is based on the results of question 16 (Do you know how to access information about sustainability on campus?) that make up 15.86%. However, the majority of respondents answered that they did not know (60.34%) and were "Not Sure" (23.79%) how to access information about sustainability on campus. These results highlight one of the reasons the A&M-Commerce population has little knowledge of sustainability issues on campus and also do not know how to get involved in sustainable development on campus. See Appendix C for survey responses.

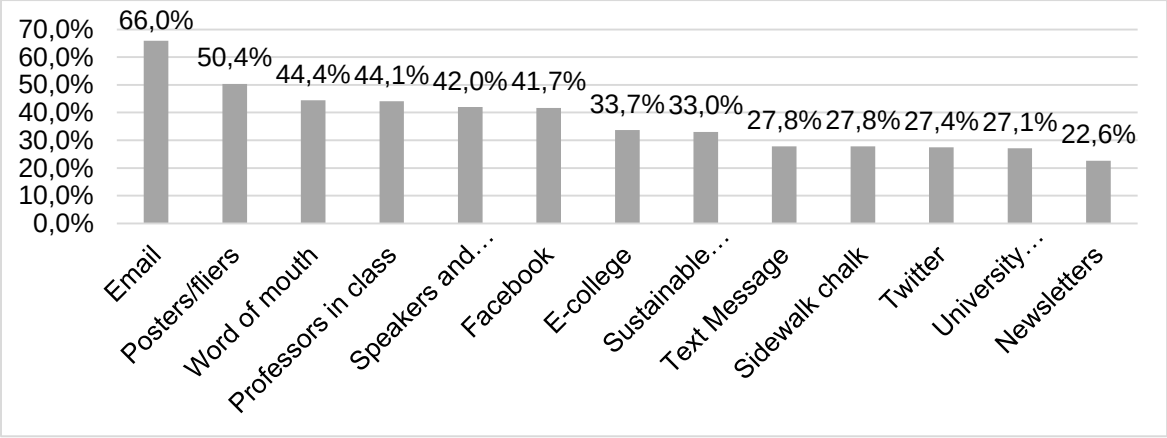

Figure 4. Preferable access to sustainability information. This figure suggests the ways students, faculty and staff of A&M-Commerce prefer to access information about sustainability. The highest percentage of respondents would like to receive such information by E-mail, and the lowest percentage goes to newsletters.

Limitations

The survey population could be increased to improve the power of the statistical tests, thus a further study should be distributed to a wider population.

Discussion

The results of the study show that the knowledge of sustainability is almost equally low for A&M-Commerce students, faculty, and staff. Most respondents associate unsustainability with environmental issues, and recycling is a widely known solution to the environmental issues. The survey results show that Texas A&M University-Commerce is known for its recycling program since the majority of respondents mentioned their contribution to the recycling program. However, some respondents mentioned that the recycling program could be further improved.

It is troubling that only half of the respondents had heard the term sustainability before, but this is also a great chance to educate students, faculty, and staff about economic, social, and environmental issues as they relate to sustainability. Particularly, the respondents could not relate economic issues to unsustainability and did not feel responsible to help make a difference on economic issues.

New students do not seem to know about the recycling program or the few opportunities A&M-Commerce offers in promoting sustainability. They are willing to participate and contribute if given the opportunity. The respondents are not aware of the EcoLions and their initiatives on campus. However, it is inspiring that new students realize the importance of living sustainably and their willingness to get involved. All they seem to need is guidance and continuous motivation. One way to motivate students, faculty, and staff to participate in sustainability initiatives is to provide incentives.

According to the results of the survey, respondents identified A&M-Commerce as being strongest in recycling and weakest in the waste management of food, utilization of water, and energy resources. This means A&M-Commerce should look into organizing projects aimed at energy and water conservation. The A&M-Commerce cafeteria should consider conducting a study to monitor food waste and look into ways of utilizing that waste, possibly by local pig farms. It would be a great idea to have an estimate of the amount of food wasted by a person in a day, a

week, a month, and a year. Making students aware of the food waste statistics and its negative effect on the environment and society might inspire the campus population to change its attitude (Whitehair & Shanklin, 2012).

Some respondents left comments preferring to have access to better tasting water. One of the options to realize it is to install filters on faucets. First of all, it would eliminate the great amount of plastic bottle waste, and second of all, it would improve the quality of life of students living on campus.

A&M-Commerce students, faculty, and staff reported that they are interested in learning about sustainability. Additionally, they would like to see the University be more supportive of sustainability and provide multiple opportunities with varying time commitments to get involved in sustainable development initiatives. Some of the most effective ways to deliver information about sustainability-related activities would be through E-mail, posters and fliers, through professors in class, and through Facebook. Besides sustainability activities and projects, students, faculty, and staff can also learn about sustainability topics from public speakers, sustainability conferences, and the University curriculum.

This study could be replicated in a few years to compare the results and see if A&M-Commerce strengthens its sustainability program and gains more respect and recognition from students, faculty, and staff.

Conclusion

Campus-wide sustainability is a comprehensive program that takes time, effort, and, most importantly, a willingness to make a difference. The first step in this process is to evaluate and understand the current university condition as it pertains to sustainability and the level of sustainability knowledge among students, faculty, and staff. To achieve some level of understanding a sustainability survey was conducted at Texas A&M University-Commerce (A&M-Commerce) which was aimed to answer four fundamental questions: How much does A&M-Commerce population already know about sustainable development? Is the A&M-Commerce population interested in learning about sustainable development? Is there interest among A&M-Commerce faculty, staff and students in contributing to sustainable development and do they feel responsible to change their behavior as it affects campus sustainability? What role does A&M-Commerce play in encouraging campus sustainability?

About 50 % of A&M-Commerce respondents have heard the term “sustainability” before. But many still do not know its significance today and its influence on future generations.

The number of survey respondents who want to learn more about sustainability is high. This is a great motivation for supporters of sustainable development on the A&M-Commerce campus. This is one need that the University could focus on meeting, benefitting from it in the long run.

The majority of A&M-Commerce faculty, staff, and students understand the effect that their actions have on the environment, society, and economy. Therefore, they are interested in contributing to the sustainable development of their campus, if given the opportunity. However, there were some respondents who were not sure how their lifestyle could influence their wellbeing and that of future generations.

A&M-Commerce campus seems to have a well-known recycling program. However, a considerable number of respondents believe that the recycling program could be further improved. The survey shows that the majority of faculty, students, and staff are unaware of the few opportunities that A&M-Commerce provides to encourage sustainability of the University. A&M-Commerce plays a significant role in educating students about sustainability. Providing opportunities and encouragement to students has a great potential in leading the way towards a more sustainable future. Given the opportunity and revised vision aimed towards campus-wide sustainability, A&M-Commerce has a chance of being included in The Princeton Review of 361 Green Colleges.

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Appendix A

Information about Being in a Research Study
Texas A&M University-Commerce

Campus-Wide Sustainability Program Study at Texas A&M University-Commerce

Viktoria Tabeleva and Dr. Andrea Graham are inviting you to take part in a research study. Viktoria Tabeleva is a junior Industrial Engineering major in the Department of Engineering and Technology. Dr. Graham, her advisor, is an Assistant Professor at Texas A&M University-Commerce in the Department of Engineering and Technology.

This survey is being conducted as a part of thesis research on campus wide sustainability at Texas A&M University-Commerce. The questions in the survey seek to better understand the knowledge, views, and behavior regarding various elements of sustainability as seen by faculty, staff and students. The results from the survey will be used to assess curriculum and programs as they relate to sustainability literacy.

Your part in the study will be to complete a survey that assesses your general perceptions and attitudes about sustainability.

It will take you about fifteen (15) minutes to complete the survey.

Risks and Discomforts

There will be minimal risks, no more than that expected in daily life.

Possible Benefits

We do not know of any way you would benefit directly from taking part in this study. However, this research may help us to understand how to better educate and involve students in campus sustainability.

Incentives

No financial or other compensation will be offered.

Protection of Privacy and Confidentiality

We will do everything we can to protect your privacy and confidentiality. We will not tell anybody outside of the research team that you were in this study or what information we collected about you in particular. The responses of the survey will be kept in Dr. Andrea Graham's office number AG/IT 213 B located in the Engineering and Technology building and kept confidential. The data will be kept for four years until spring 2020.

Choosing to Be in the Study

You do not have to be in this study. Participation is voluntary. You may choose not to take part and you may choose to stop taking part at any time without penalty. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study.

Contact Information

If you have any questions or concerns about this study or if any problems arise, please contact the researcher at

Viktoria Tabeleva
Department of Engineering and Technology
Texas A&M University-Commerce
903-340-5381
vtabeleva@leomail.tamuc.edu

or the advisor at

Dr. Andrea Graham
Department of Engineering and Technology
Texas A&M University-Commerce
903-468-8737
Andrea.Graham@tamuc.edu

If you have any questions or concerns about your rights in this research study, please contact the IRB Chair at

Dr. Betty Block
Chair, Institutional Review Board (IRB)
Department of Health & Human Performance
Texas A&M University-Commerce
Commerce, TX 75429-3011
(903) 886-5545
irb@tamuc.edu

Consent

The signature below affirms that the undersigned is at least 18 years old, has received a copy of this consent form, has understood the above information, and agrees to voluntarily participate in this research.

Participant's signature: _____ Date: _____

A copy of this form will be given to you.

Appendix B

2016 Sustainability Survey Data Set

Question 1 – Have you heard the term "sustainability" used at Texas A&M University-Commerce?

- ☐ Yes
- ☐ No
- ☐ Not Sure

Question 2 – If you said "yes" to the above question, please list the places or describe the instances where you have encountered the term "sustainability" at Texas A&M University-Commerce.

- ☐ Faculty
- ☐ Friend
- ☐ Parent
- ☐ Social Media
- ☐ Other Specify: _____

Question 3 – For the following issues, indicate how KNOWLEDGEABLE you feel you are about them as it pertains to sustainability. Rate each issue on a scale of 1-5, 1 representing having no knowledge about the issue and 5 representing feeling very knowledgeable about the issue.

- ☐ Waste
- ☐ Safety and Security
- ☐ Unemployment
- ☐ Energy Use
- ☐ Water Use
- ☐ Food Waste
- ☐ Education
- ☐ Health and Wellness
- ☐ Local Business/Local Economy

Question 4 – Please indicate how CONCERNED you are about each of the following issues as they pertain to sustainability. Rate on a scale of 1-5 where 1 is you are not at all concerned about this issue and 5 is you are very concerned about this issue.

- ☐ Waste
- ☐ Safety and Security
- ☐ Unemployment

- Energy Use
- Water Use
- Food Waste
- Education
- Health and Wellness
- Local Business/Local Economy

Question 5 – Please indicate how SIGNIFICANT you feel your personal effort might affect change(s) regarding the following issues as they pertain to sustainability. Rate on a scale of 1-5 where 1 is how your personal effort is insignificant and 5 is how your personal effort is very significant.

- Waste
- Safety and Security
- Unemployment
- Energy Use
- Water Use
- Food Waste
- Education
- Health and Wellness
- Local Business/Local Economy

Question 6 – Please respond to this statement: I have a personal responsibility to help make a difference on ENVIRONMENTAL issues like waste, energy and water use, food waste.

- Strongly Disagree
- Disagree
- Slightly Disagree
- Slightly Agree
- Agree
- Strongly Agree

Question 7 - Please respond to this statement: I have a personal responsibility to help make a difference on SOCIAL issues like safety and security, education, and health and wellness.

- Strongly Disagree
- Disagree
- Slightly Disagree
- Slightly Agree
- Agree
- Strongly Agree

Question 8 - Please respond to this statement: I have a personal responsibility to help make a difference on ECONOMIC issues like unemployment and local business/local economy.

- Strongly Disagree
- Disagree
- Slightly Disagree
- Slightly Agree
- Agree
- Strongly Agree

Question 9 – Which of the following choices or activities describe your current lifestyle? (Check all that apply)

- Take public transit
- Carpool
- Bike/walk
- Buy locally grown, seasonal products
- Buy organic foods when available
- Eat lower on the food chain (less meat)
- Purchase recycled or bulk products
- Participate in student organizations
- Exercise
- Seek relationships with diverse groups of people

- ☐ Vote
- ☐ Volunteer with nonprofit organizations
- ☐ Turn off lights when not in use
- ☐ Turn the heat down when not home
- ☐ Wash clothes in cold or warm water (instead of hot)
- ☐ Take short showers (5 minutes or less)
- ☐ Drink tap water (use filter) instead of bottled
- ☐ Use a reusable water bottle
- ☐ Reduce/Reuse/Recycle
- ☐ Double-side copies and print jobs
- ☐ Use green cleaning products
- ☐ None of these

Question 10 – Which sustainability related activities or resources are you AWARE of and/or PARTICIPATE in on the TAMUC campus? (Please list).

_____

_____

_____

Question 11 – In what areas of sustainability would you say TAMUC is strongest?

a. Personal response to be written by student respondents

Question 12 – In what areas of sustainability would you say TAMUC is weakest?

a. Personal response to be written by student respondents

Question 13 – On what sustainability efforts would you like to see TAMUC focus?

a. Personal response to be written by student respondents

Question 14 – Are you interested in learning more about sustainability?

- ☐ Yes
- ☐ No
- ☐ Not Sure

Question 15 – Do you know how to access information about sustainability on campus?

- ☐ Yes
- ☐ No
- ☐ Not Sure

Question 16 – What would be the best ways for students to access information about sustainability on campus?

- ☐ E-college
- ☐ Email
- ☐ Sustainable Community Development Initiative website
- ☐ Facebook
- ☐ University Newspaper
- ☐ Newsletters
- ☐ Posters/fliers
- ☐ Sidewalk Chalk
- ☐ Speakers and events
- ☐ Professors in class
- ☐ Twitter
- ☐ Word of mouth

Question 17 – In your opinion, on a scale from 1 – 10, with one (1) being seriously deficient and ten (10) being exceeding your expectations, how SUPPORTIVE of sustainability is TAMUC?

- ☐ 1
- ☐ 2
- ☐ 3

- 4
- 5
- 6
- 7
- 8
- 9
- 10

Question 18 - In your opinion, on a scale from 1 – 10, with one (1) being seriously deficient and ten (10) being exceeding your expectations, how successful has TAMUC been at PROVIDING OPPORTUNITIES on campus for YOU to be engaged in sustainability?

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

Question 19 (Optional) – Academic Year

- Freshman
- Sophomore
- Junior
- Senior
- 5+ Year Senior
- Graduate Student

Question 20 (Optional) – Age

a. Personal response to be written by student respondents

Question 21 (Optional) – Gender

- Male
- Female
- Other

Question 22 (Optional) – Where do you live?

- On Campus
- Off Campus

Question 23 (Optional) – In which college is your major area of study?

- College of Education and Humanities
- College of Business
- College of Humanities, Social Sciences, & Arts
- College of Science and Engineering
- College of Agriculture
- Undecided/Unsure

Question 24 (Optional) – Race

- White/Non-Hispanic
- Black/Non-Hispanic
- Hispanic
- American Indian or Alaskan Native
- Asian or Pacific Islander
- Mixed Race
- Other

Appendix C

Default Report
2016 Sustainability Survey at A&M-Commerce
October 9, 2016

Q0 - Information about being in a Research Study
Texas A&M University-Commerce
Campus-Wide Sustainability Program Study at Texas A&M University-Commerce

Viktoria Tabeleva and Dr. Andrea Graham are inviting you to take part in a research study. Viktoria Tabeleva is a junior Industrial Engineering major in the Department of Engineering and Technology. Dr. Graham, her advisor, is an Assistant Professor at Texas A&M University-Commerce in the Department of Engineering and Technology. This survey is being conducted as a part of thesis research on campus wide sustainability at Texas A&M University-Commerce. The questions in the survey seek to better understand the knowledge, views, and behavior regarding various elements of sustainability as seen by faculty, staff and students. The results from the survey will be used to assess curriculum and programs as they relate to sustainability literacy. Your part in the study will be to complete a survey that assesses your general perceptions and attitudes about sustainability. It will take you about fifteen (15) minutes to complete the survey.

Risks and Discomforts

There will be minimal risks, no more than that expected in daily life.

Possible Benefits

This survey would not benefit you directly from taking part in this study. However, this research may help you to understand how to better educate and involve students in campus sustainability.

Incentives

No financial or other compensation will be offered.

Protection of Privacy and Confidentiality

Those conducting the survey will do everything they can to protect your privacy and confidentiality. They will not tell anybody outside of the research team that you were in this study or what information they collected about you in particular. The responses of the survey will be kept in Dr. Andrea Graham's office number AG/IT 213 B located in the Engineering and Technology building and kept confidential. The data will be kept for four years until spring 2020.

Choosing to Be in the Study

You do not have to be in this study. Participation is voluntary. You may choose not to take part and you may choose to stop taking part at any time without penalty. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study.

Contact Information

If you have any questions or concerns about this study or if any problems arise, you should contact the researcher at

Viktoria Tabeleva
Department of Engineering and Technology
Texas A&M University-Commerce
903-340-5381
vtabeleva@leomail.tamuc.edu
or the advisor at
Dr. Andrea Graham
Department of Engineering and Technology
Texas A&M University-Commerce
903-468-8737
Andrea.Graham@tamuc.edu

If you have any questions or concerns about your rights in this research study, you should contact the IRB Chair at

Dr. Tara Tietjen-Smith Chair,
Institutional Review Board (IRB)
Department of Health & Human Performance
Texas A&M University-Commerce
Commerce, TX 75429-3011
(903) - 886 - 5545
IRB@tamuc.edu

Consent

I have read the above information, and I affirm that I am at least 18 years old, have received a copy of this consent form, have understood the above information, and agree to voluntarily participate in this survey.

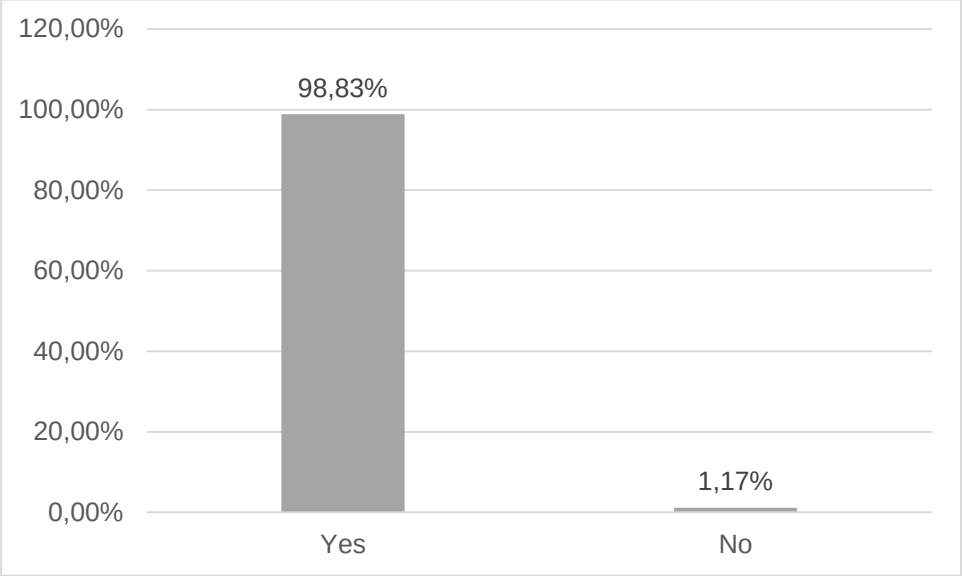

Figure 5. Percentage of respondents who agreed and disagreed to participate in the survey.

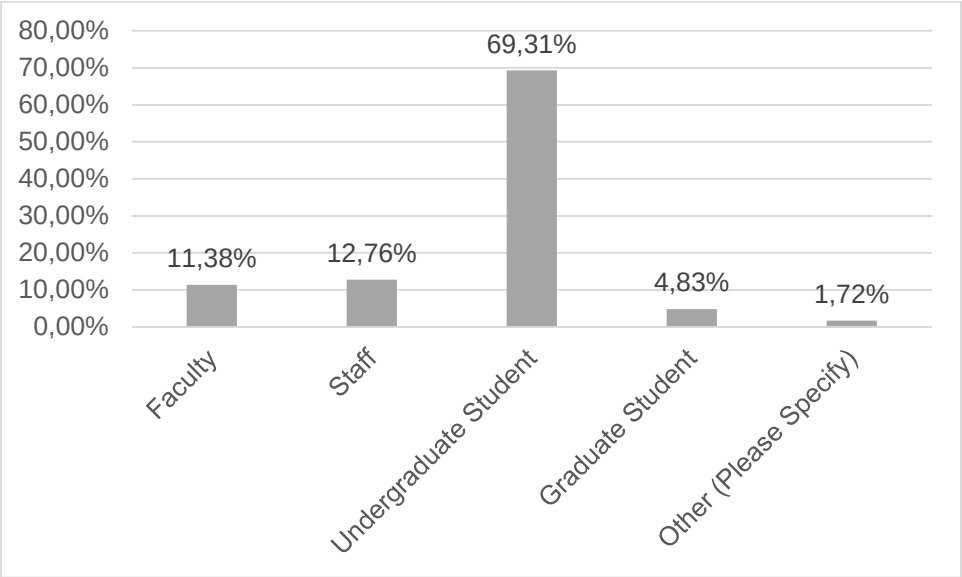

Figure 6. Survey population in percentages.

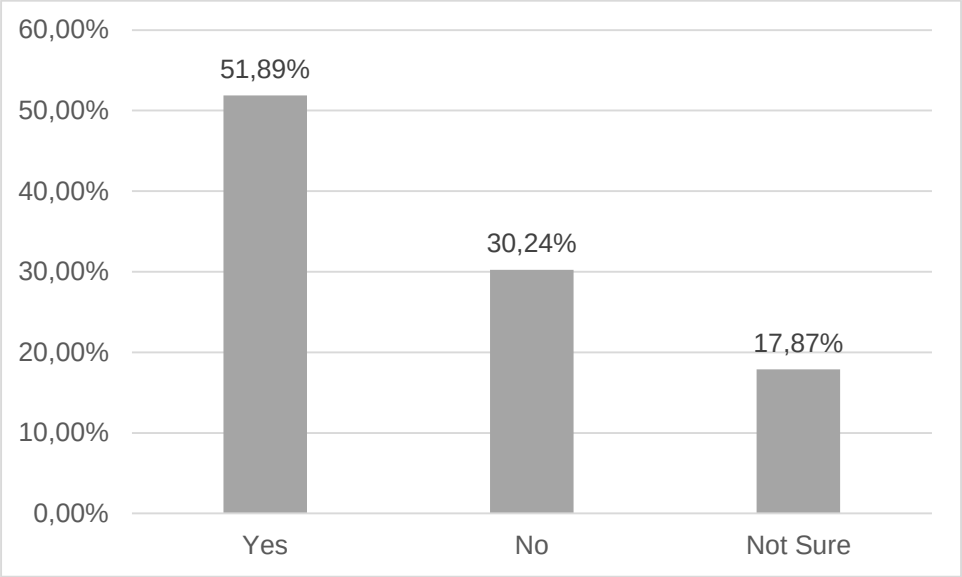

Figure 7. Responses to the question: “Have you heard the term "sustainability" used at Texas A&M University-Commerce?”

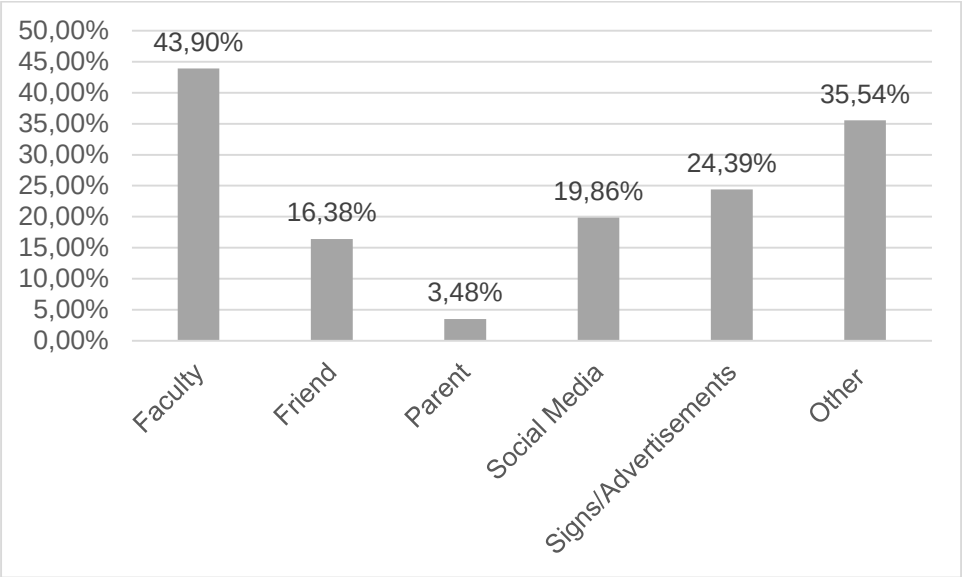

Figure 8. Places or instances where the respondents had encountered the term "sustainability" at Texas A&M University-Commerce.

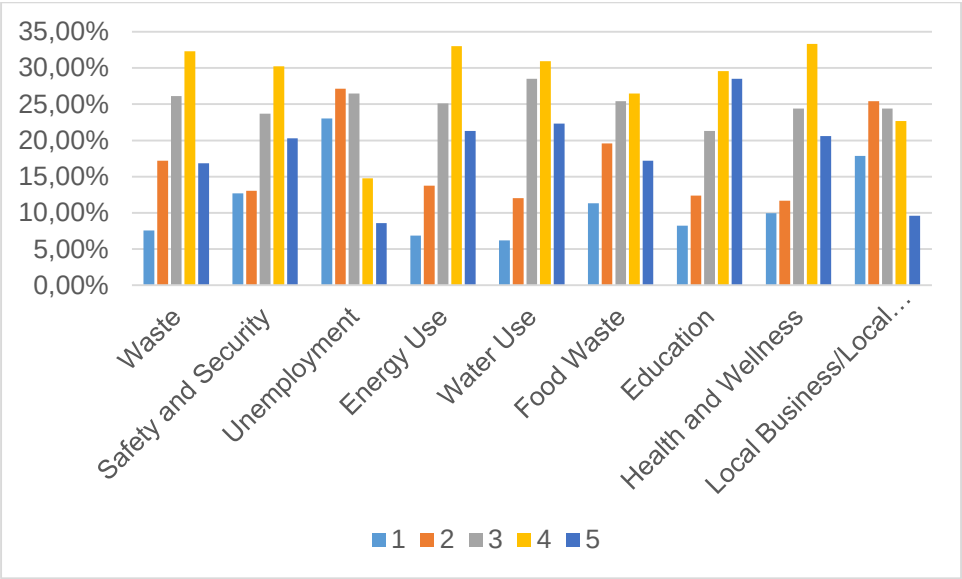

Figure 9. Respondents rating about how KNOWLEDGEABLE they feel about sustainability issues. Ratings are based on a scale of 1-5, 1 representing having no knowledge about the issue and 5 representing feeling very knowledgeable about the issue.

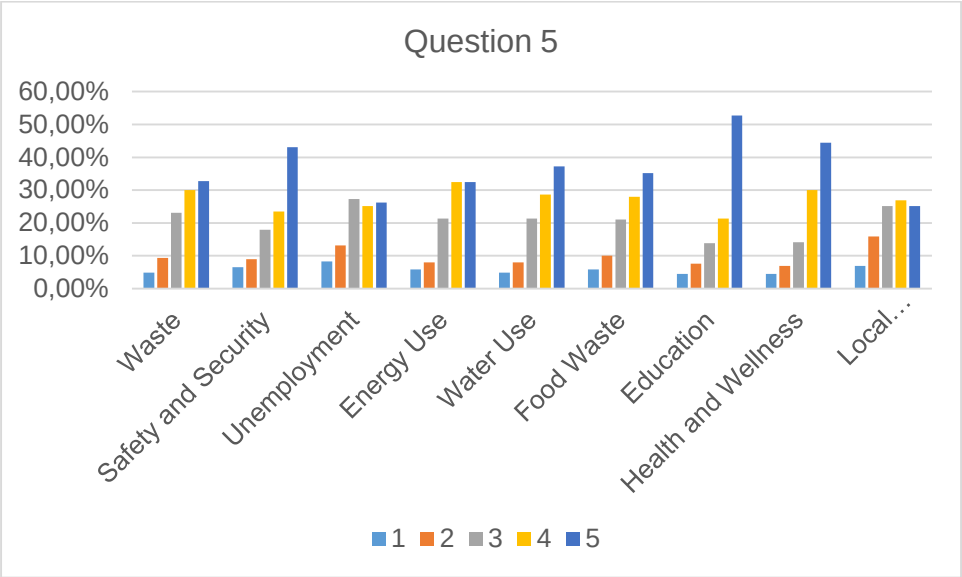

Figure 10. Respondents rating about how CONCERNED they feel about sustainability issues. Ratings are based on a scale of 1-5 where 1 represents being not at all concerned about the issue and 5 represents being very concerned about the issue.

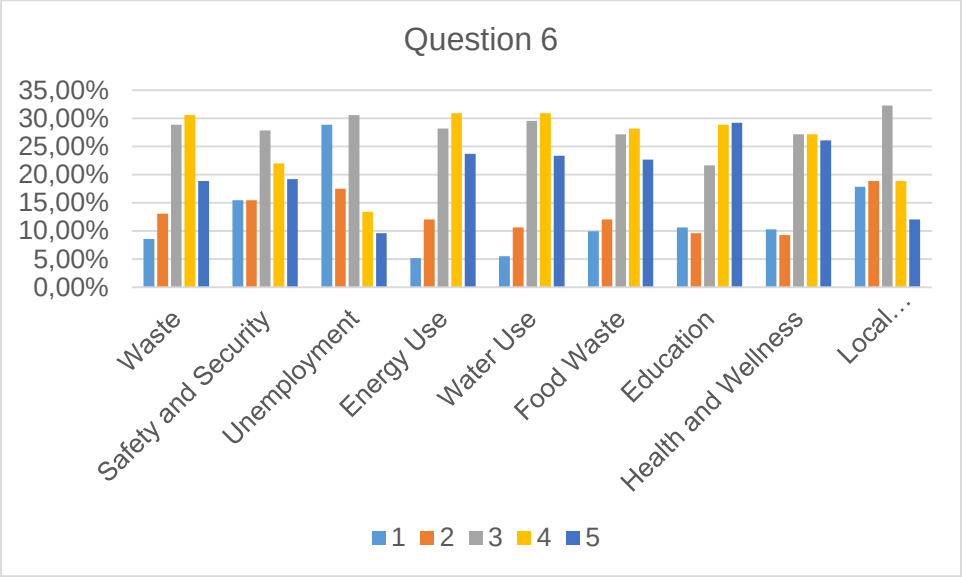

Figure 11. Respondents rating about how SIGNIFICANT they feel their personal effort might affect change(s) regarding sustainability issues. Ratings are based on a scale of 1-5 where 1 is how their personal effort is insignificant and 5 is how their personal effort is very significant.

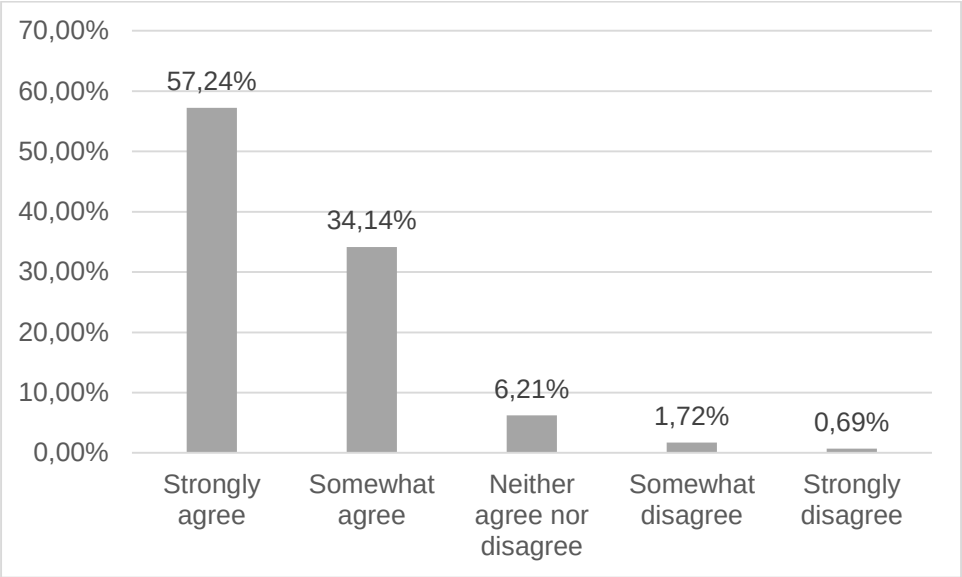

Figure 12. Responses to the statement: I have a personal responsibility to help make a difference on environmental issues like waste, energy and water use, food waste.

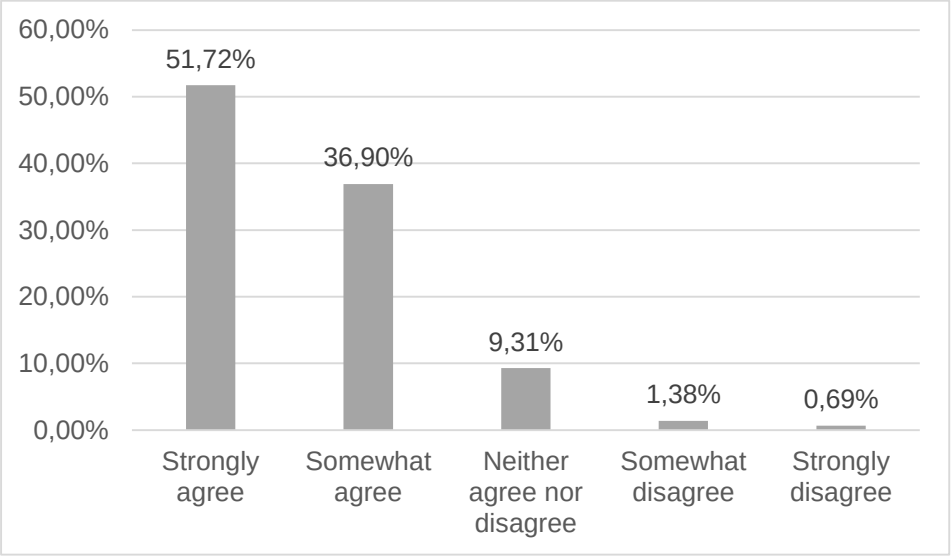

Figure 13. Responses to the statement: I have a personal responsibility to help make a difference on social issues like safety and security, education, and health and wellness.

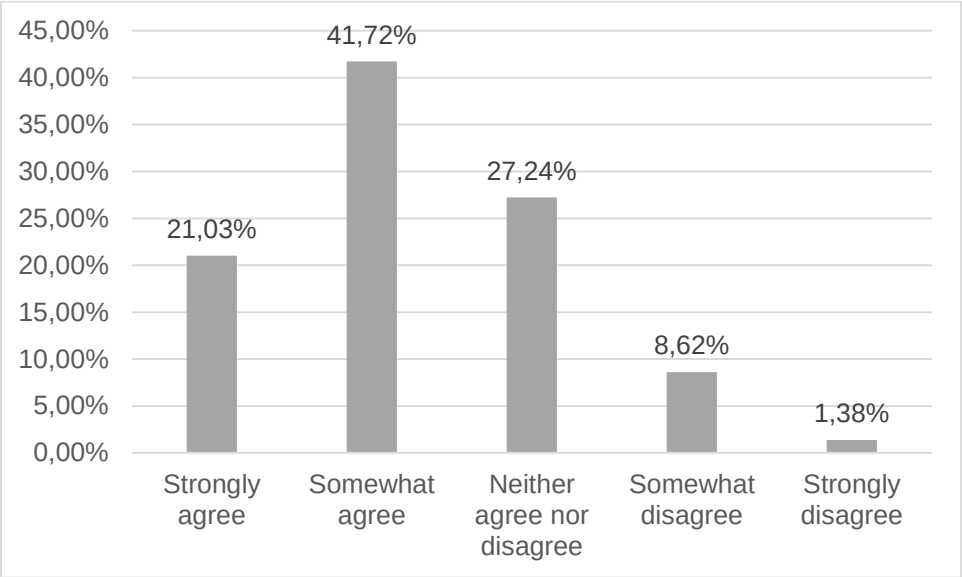

Figure 14. Responses to the statement: I have a personal responsibility to help make a difference on economic issues like unemployment and local business/local economy.

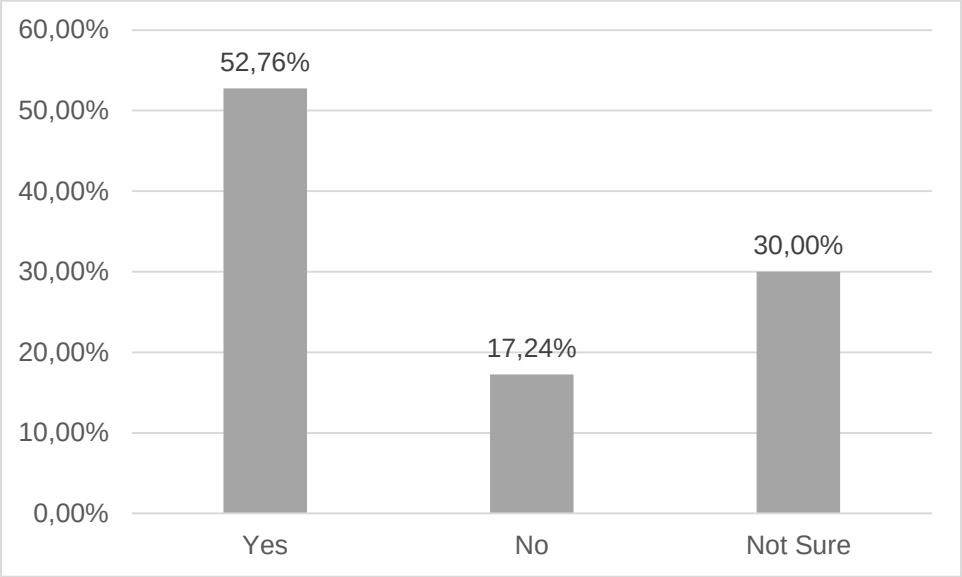

Figure 15. Answers to whether the respondents are interested in learning more about sustainability.

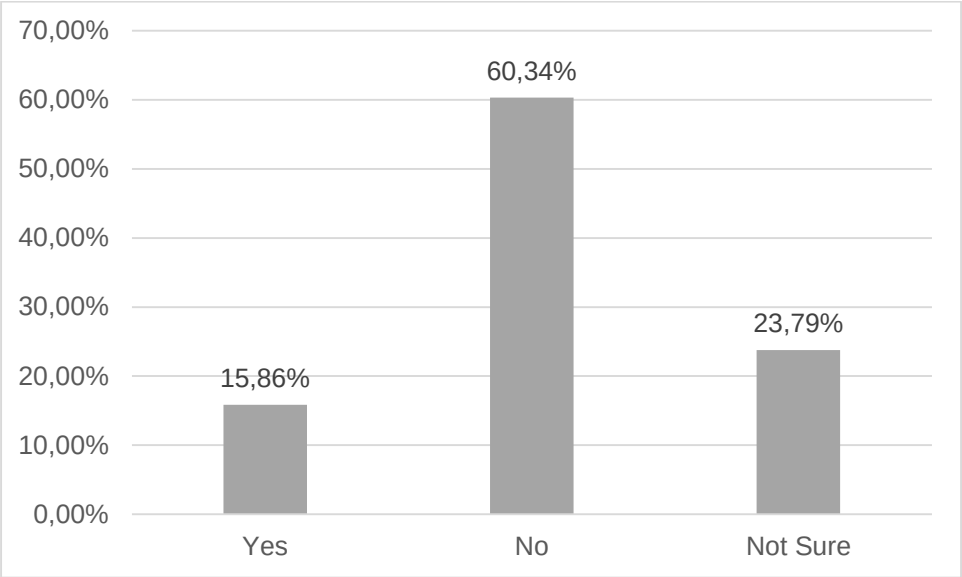

Figure 16. Answers to whether the respondents know how to access information about sustainability on campus.

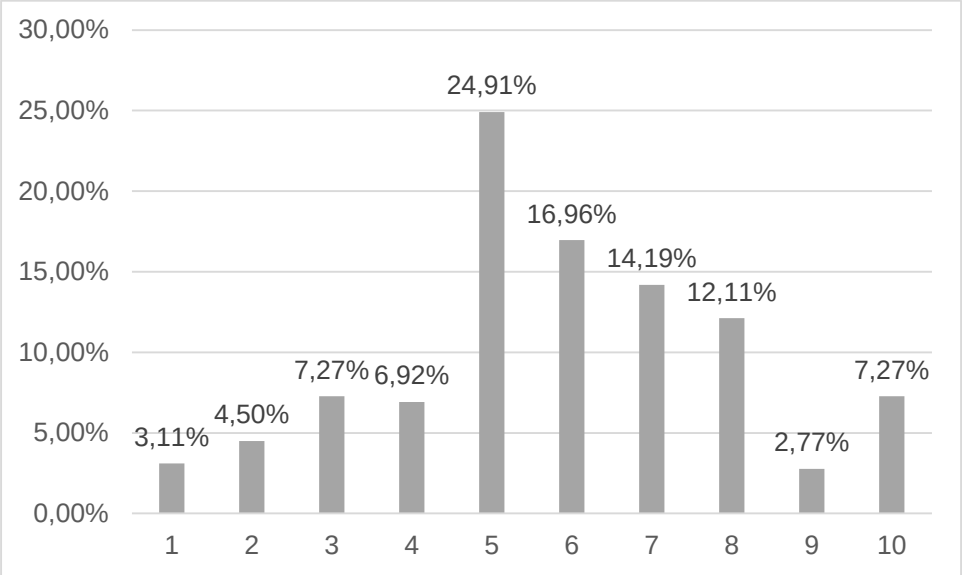

Figure 17. Scores assigned by the respondents to A&M-Commerce of being supportive of campus sustainability on a scale from 1 - 10, with one (1) being seriously deficient and ten (10) being exceeding their expectations.

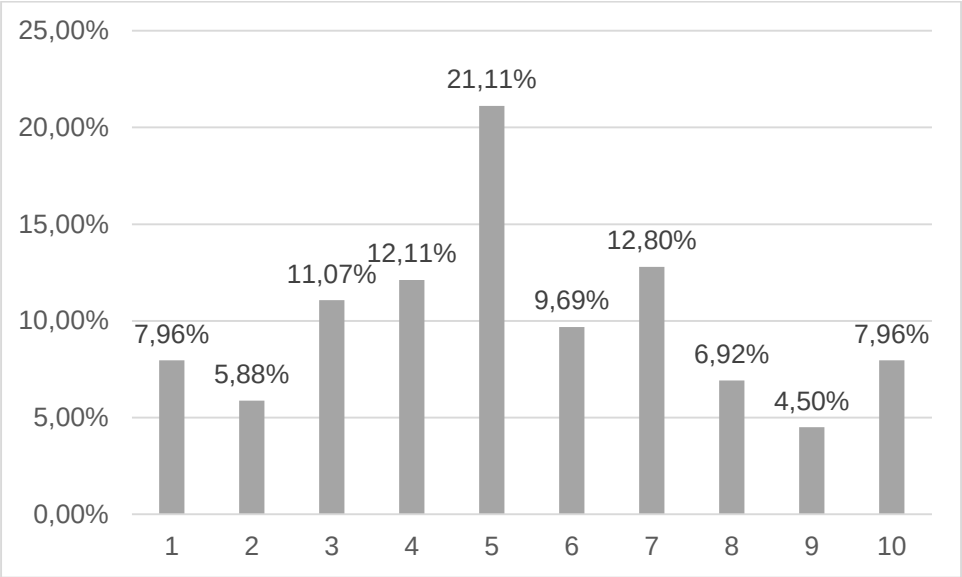

Figure 18. Scores assigned by the respondents to A&M-Commerce of providing opportunities on campus to be engaged in sustainability on a scale from 1 - 10, with one (1) being seriously deficient and ten (10) being exceeding their expectations.

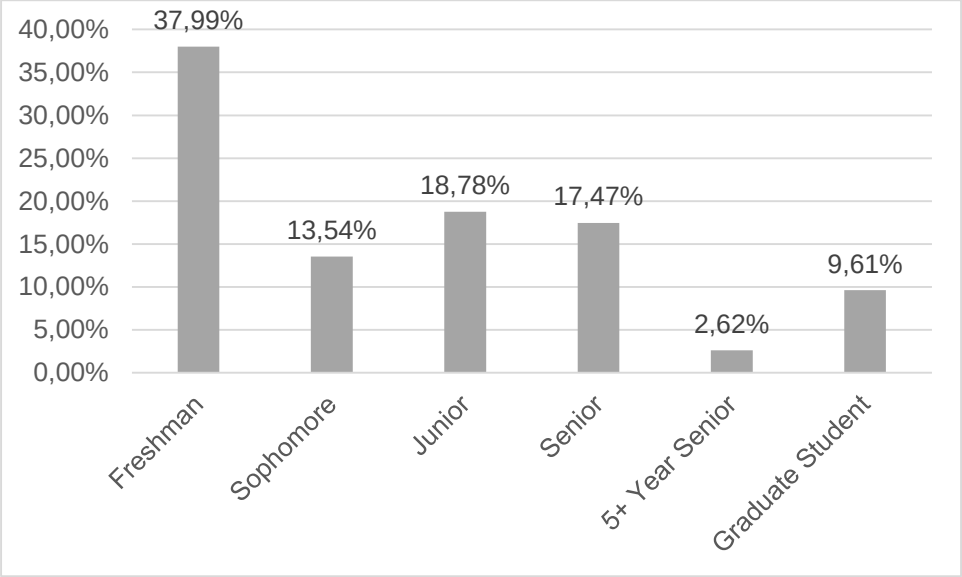

Figure 19. Respondents' academic year at A&M-Commerce.

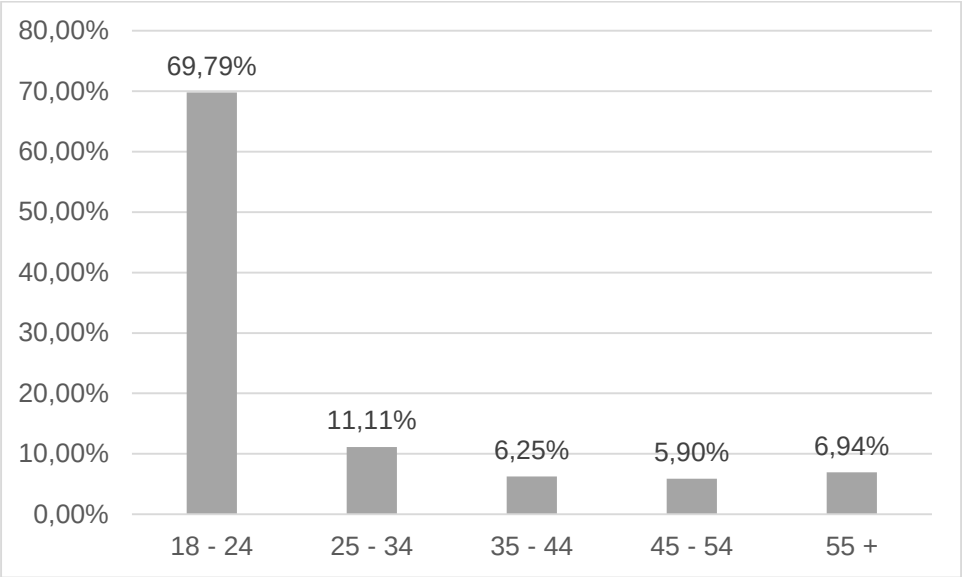

Figure 20. Respondents' age.

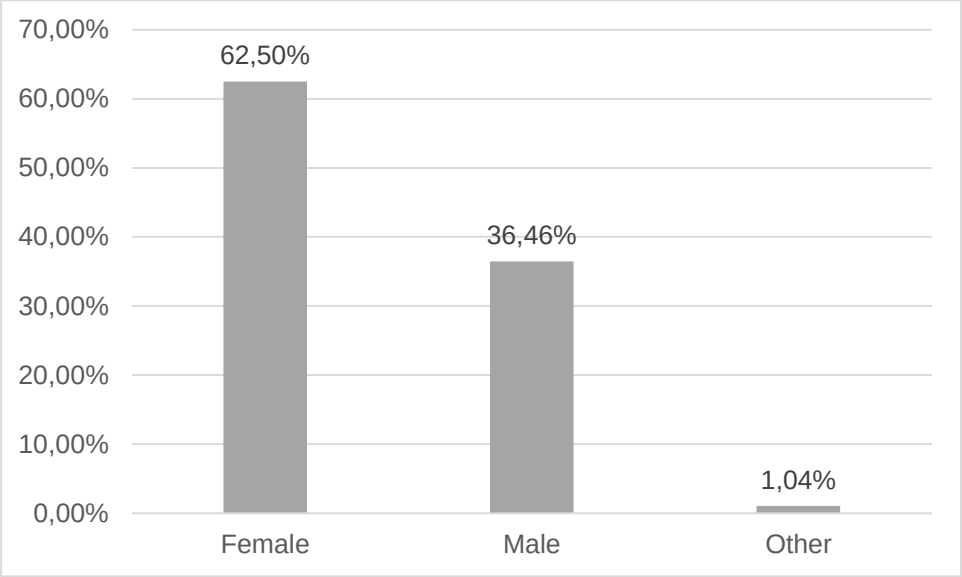

Figure 21. Respondents' gender.

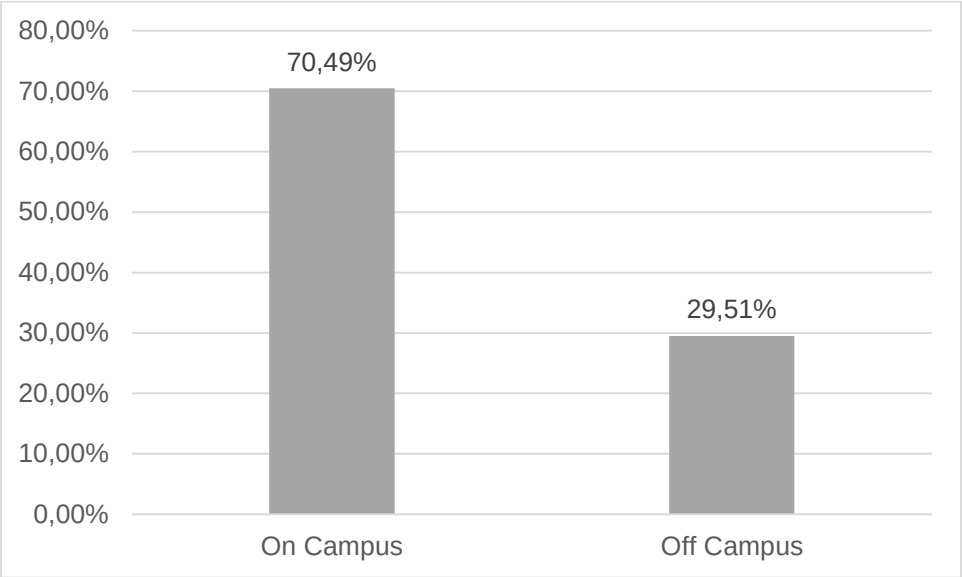

Figure 22. Percentages of respondents who stay on- and off- campus.

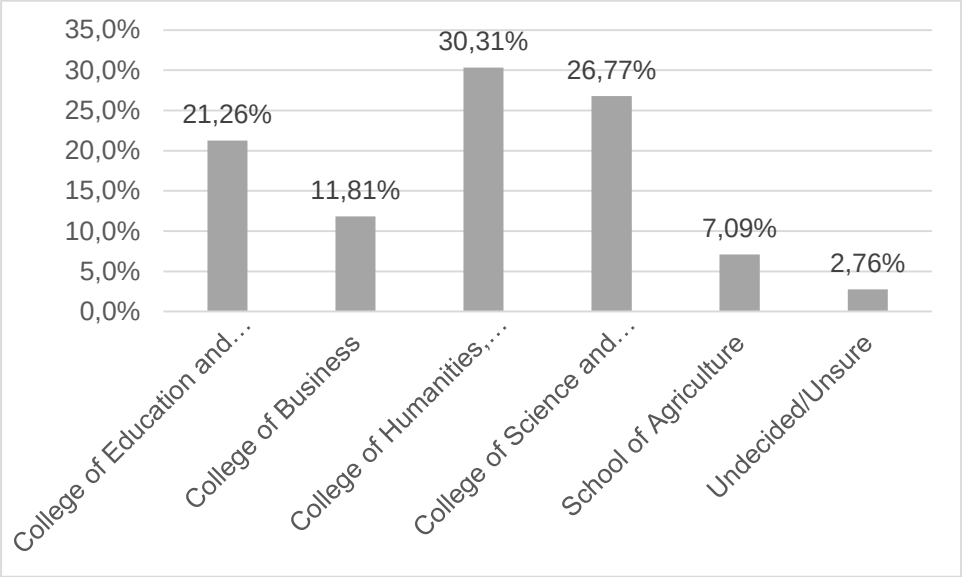

Figure 23. College to which respondents belong to.

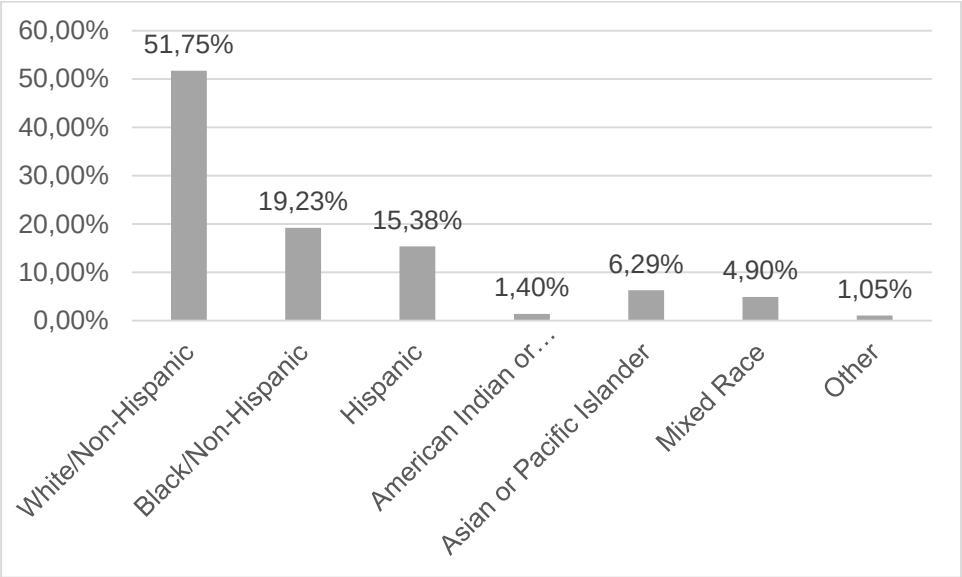

Figure 24. Respondents' race.

JUSTIFICATION OF MANUFACTURING CELL ROBOTIZATION USING SIMULATION AND PRODUCTION ANALYSIS

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ABSTRACT

The scope of this research paper is to focus mainly on a trading off benefits for multi scenarios base of completely automating a manufacturing cell for plastic products of fuel tank manufacturing lines as one of the automotive components. Technically, replacing a repetitive manufacturing operation with a human-interaction by an industrial robotic system is not only a feasible implementation in terms of throughput analysis. Ergonomically, the repetitive operation raises the potential injuries in the work place. Injuries and worker complaints due to poor ergonomic design in plastic fuel tank manufacturing lines is an ever growing issue due to two main reason: rapidly growing demands in the automotive industry and the increase in production of large heavy duty pickup trucks and mid-size SUVs. With the increase in production of these large vehicles comes an increase in ergonomic issues for human workers. A simulation model has been developed is to focus mainly on differences of taking the labor completely out of the work and replacing with an industrial robot. The utilization of the robot has been considered an indicative of the bottlenecking factor. The scenario is the first ever that has performed for the company under study. Because the company has never implemented robots in the manufacturing cell as well as the return of investment for the equipment, it is a struggle to decide to use industrial robot without effective evidence that can impact on the output of the production. The results show the manufacturing line has an increased trend in output, and the implementation of the robot has been justified.

Keywords: System Simulation, Manufacturing Cell-Robotization, Improvements Scenarios

1 Introduction

Investigating for economic justifications to adopt an upgrade plan or replacement partially automated manufacturing system has been a major stream for most industrial organizations since the earlier generation of digital control systems considered to be replaced with the traditional monitoring and analyzing means. The key is to recognize that a change of one or more of current hardware technologies brings with wide chance to justify making an investment leading to future production benefits. But improvement cannot be realized unless the upgrade or replacement also

includes the advantage of adopting new or different manufacturing technologies than the current system was capable of.

In a manufacturing system to make an order running the system, describing the operation as discrete event arrives for each machine in the system and impact manual running for comparing form may is not always available to represent enhancing the decision distribution (Akcay, A., & Biller, B. 2014). Simulation is used more often in the early design phase for the support of production planning and control-related decisions (Ziarnetzky et al. 2014). Discrete events simulation commonly used in modeling and analyzing additions and modifications of complex manufacturing systems as an offline tool contributing towards the right decision to be made as well as get the justifications enhanced by interfacing with the optimum package of scenarios to target the identify the best configuration that results in the optimum performance of the manufacturing system (Phatak et al. 2014). Robotizing a partially automated operation implies increasing the flexibility of a manufacturing system; while the automation has advantages like reduction in number of workers, efficient planning, best possible quality, and highest level of productivity with the same number of resources, some technological problems like fully automated environments are among the known disadvantages such the level of the complexity in terms of system control (Ic, Y. T., Dengiz et al. 2014).

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(Ic, Y. T., Dengiz et al. 2014). The classical manufacturing tasks planning system consisting of machines processing time typically as homogeneous events of discrete system. However, in order to simulate a production line, heterogeneous tasks for the system need to be consisting as various types of machines in the line are required (Kang et al. 2014). Consequently, the industrial companies develop different scenarios on the current system to differentiate the plans for better production model at the same line requiring different resources utilization during the operating (Biele & Monch. 2015).

In this applied research work, a set of test and analysis has been done in one of the supplier companies that manufacture plastic products used through the automotive industry in the North America. The product is a treated plastic material tank that produced in a system of manufacturing processes which are currently partially automated, a set of automated machine have been installed and linked with a different types of transportation process. Productivity issues and other human-machine interaction have recently emerged in the facility. It is well-known that potential injuries and worker complaints are due to relying on the labor to carry, loaded/unloaded, and setup manufacturing processes. Inappropriate design of an ergonomical potential in such plastic fuel tank manufacturing lines is an ever growing issue due to two main reason as well as rapidly growing demands in the automotive industry; and especially at this company, the increase in production of large heavy-duty pickup trucks and mid-size SUVs. With the increase in production of these large vehicles comes with a decrease in the production attributes and an increase in ergonomic issues for human workers. Studying labor capability and limitations in a workplace can be a comprehensive strategy for the production and ergonomics improvements. Extensive data collection of the plastic fuel manufacturing line can be used to build a simulation that can compare current processes with human workers with an automated one. The ability to mimic a real life manufacturing process without investing costs into making changes on the actual floor is a great way to provide evidence of change so that there is minimal risk.

The paper is organized as to describe important of the simulation providing justifications of the automation, especially installation an industrial robotics system as an introduction in Section 2. In addition, related work is discussed in the section. Defining the research problem and as well as major assumptions of the simulation mode in Section 3. These building blocks are used to model and simulate by Rowell software (ARENA 12.6) In Section 4. Some simulation results are presented. Finally, we concluded and discussed future research directions.

2 Research Probem Statements

The overall experience of an operator can vary on this plastic fuel injection manufacturing line depending on his or her anthropometry. For example, a very tall and strong man/woman may have no complaints about lifting and transferring a 40 pound fuel tank on the line, but a shorter and or slender man/woman may complain of having pain. However, after an ergonomic study was performed, it was shown that no matter what the anthropometry of the worker, with the demands of the manufacturing line, there is a level of stress on the body that calls for a solution. Since the plant houses over 10 different fuel tank manufacturing lines and fuel tank weights vary drastically depending on the vehicle program, this research paper will be using Line C1XX FWD (type of vehicle will not be disclosed for privacy reasons). This fuel tank weighs about 35 pounds.

This simulation model will be the first ever performed for this company and the scope of this research paper will focus mainly on the differences (if any) that will be seen when taking the human operator completely out of the work scenario and replacing it with a robot. Because this company has never employed a robot in this station it is a struggle to understand the effect it can have on the output of the product. Another key point that has been mentioned by company leadership is the need for a return in investment for the equipment. Because the robot would be considered capital, the cost of a robot would come directly from the company's bank account. Therefore, the overall objectives of this study are:

1. Collect time study data for the simulation model that will allow for an accurate depiction of the real life manufacturing line and be sure that baseline simulation output equates that of the real line.
2. Use this information to develop a simulation (using Arena software) that shows the fuel tank flow through the PMC area given the different methods of transport: human and robot.
3. Analyze different scenarios on the basis of results. If system yields a higher output with a robot, then research will be complete. If system yields equal or less output with a robot, change PMC machine count or BMM process times to find best case scenario.

In this plant there are 3, shifts a day that are 8 hours long. The plant runs 5 days a week and plans according to a 90% uptime schedule. There is a total of 50 lunch break a shift, however due to the scheduling of all breaks; they have no influence on the simulation model. The area in

which this simulation model will be examining is the Post Mold Cooling portion of the entire fuel tank manufacturing line. The first station is the Blow Molding Machine (BMM), which extrudes a plastic fuel tank and drops it on a chute in front of the human operator. The tank is close to 110 degrees Celsius at this point; therefore heat resistant gloves must be worn for tank handling. The operator then de-flashes the tank and places the flash on a conveyor which sends it to be re-ground, weighs the tank, and places a traceability label onto the tank. After these functions are performed the operator must lift the tank, being careful not to rest it on their bodies because of the high temperature, and walk several steps to the Post Mold Cooling Machines (PMC) where they load the tank into the mold inside the PMC. Usually after loading a PMC, the second PMC machine located parallel to the first PMC open up and exposes a cooled tank for unloading. The operator therefore turns around, unloads the second PMC and walks another several steps to load the Vertical Cooling Tower (VCT) for additional cooling. The Operator then walks back to the weigh table, loads a new e-ring into the BMM and the process starts all over again. Due to this arduous process, operators are moved downstream from the Post Mold Cooling area every thirty minutes. All operators get a lunch break but they do not affect the manufacturing line because there is always an operator to relieve another operator when they are ready for break.

3 INPUT DATA ANALYSIS

The data collection process for this research paper was easily organized due to the easily obtained real time data collected by the team of industrial engineers in the fuel tank plant. A line balancing document was created for the C1XX FWD; (Appendices A & B), manufacturing line and time studies were performed to collect the walk, weight, and working times of machines and operator which can be seen in the appendix of this paper. Since a different operator runs the equipment every 30 minutes, there was obviously variation in the time study data. For this reason, an average data value was calculated for all data points needed to create this simulation model.

Due to the simplicity of this section of the manufacturing line, only times needed to be taken. The only differences in data collected were that between human operator time and machine times. Machine times in this manufacturing line are set to a constant and are available on the BMM and PMC machines for anyone to read. This made collecting this data very easy. The most difficult portion of the data collection for this model was when working with different operators. Due to the amount of things happening all at once in this station, it was deemed necessary to have two

industrial engineers collecting operator time data at the same time to make sure there was less error.

4 SIMULATION MODEL AND METHODOLOGY

4.1 Modeling and Simulation

Simulations allow for a model to be created that predicts how the inputs affect the outputs of a process before resources and time are dedicated to tangibly creating the model being simulated. Since this can, with some accuracy and precision, determine the results of something that has not actually been made, it's a powerful tool for almost any real life applications. To this extent the scenarios that we want to compare can be created relatively quickly without the capital invest as well as the trial and error that would be involved in building the real life application.

4.2 Design System and Description

To meet the goals set forth by the scope of this paper we first needed to model and simulate the current process to use as a basis for comparisons for improvement. ARENA was used to layout the model and the time data previously collected were inserted into the model. A few liberties were taken to make the modeling process simpler, yet meet the real world lines actual processing. An example of this is the PMC portion of the line where an operator would remove and fuel tank from one PMC while placing one in the second PMC. This "on-off" process is still linear as the operator can only be doing one task at a time, so it was modelled linearly instead of two separate parallel processes.

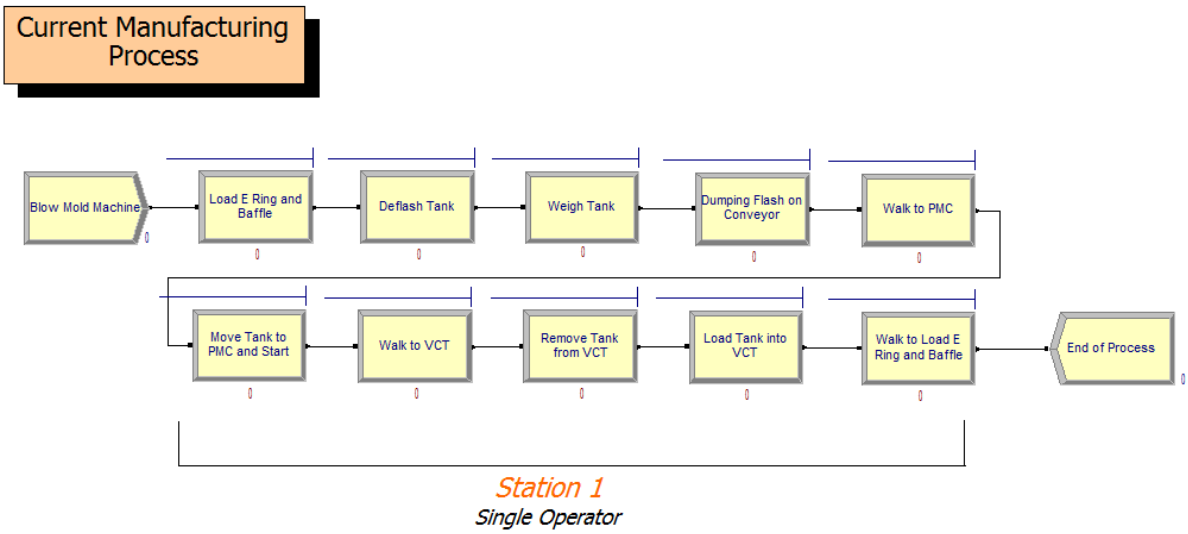

Figure 1: Current Manufacturing Process

To validate our simulation we compared the output to the current output done from current shift output data. We were within a margin of 5. By validating our data we not only proved out the simulation, but also were able to determine that the blow mold machine was the dependent variable for the outcome. Logically this seems simply apparent, the more gas tanks made the more that reach the end of the process of "VCT" equipment. By tweaking the input time we determined our range moving forward would be between 55-80sec where 80sec was the current established baseline and 55sec was the goal for future continuous improvement on the line.

4.3 Design of Experiments/Scenario Analysis

Table I is the final data table with our collected data for the DoE/Scenario analysis performed. As the data table shows going left to right the improvements in the line has an increased trend in output. While this could just be justified by the addition of blow mold machines, and is related, it's important to note the trend that takes place by the robot and utilizations. The robot section is indicative of the bottlenecking factor. For most of the lines no bottlenecking occurred until four PMCs were added with an additional blow molder. This means that we "went over" the utilization of system. By taking the average cycle time (80-55/2) we determined a relatively normal introduction of fuel tanks into the system. This cycle time on two blow mold machines gave us the perfect utilization to the system with minimal bottlenecking.

Table I: DoE Scenario Table

5

DoE Scenario Table	Current Manufacturing Process	Proposed Manufacturing Process	Proposed Manufacturing Process (Reduced Cycle Time)	Additional 4 PMCs	Additional 4 PMCs (Reduced Cycle Time)	4 PMCs + 2 Blow Molders	4 PMCs + 2 Blow Molders	4 PMCs + 2 Blow Molders
Blow Mold Cycle Time	80s	80s	55s	80s	55s	80s	55s	67.5
Total Output	384	357	452	358	520	712	890	834
Utilization								
Operator	62%	47%		32.50%	47.31%	65%	94.55%	77.07%
PMC 1		77.40%	99.50%	37.78%	58.19%	79.96%	99.27%	93.67%
PMC 2		79.39%	98.76%	35.91%	52.39%	69.43%	97.89%	83.68%
PMC 3				40.67%	59.75%	82.76%	98.63%	95.46%
PMC 4				43.75%	59.52%	82.51%	99.26%	96.25%
Robot		7.4%	9%	8.30%	12.19%	16.67%	20.90%	19.54%
Bottleneck								
Robot Seize 1		0.48	17.92	0	0	0	20.19	3.22
Robot Seize 2		0.61	18.19	0	0	0	8.46	1.11
Robot Seize 3				0	0	0	25.30	2.8
Robot Seize 4				0	0	0	26.07	4.3

Analyses and Discussion

Once the initial baseline data was collected we changed the model to reflect the scope of the project. By changing the PMC stations we would need to add a conveyor that would remove operator walking time as well as add a robot that removes and adds the gas tanks in order to be cooled.

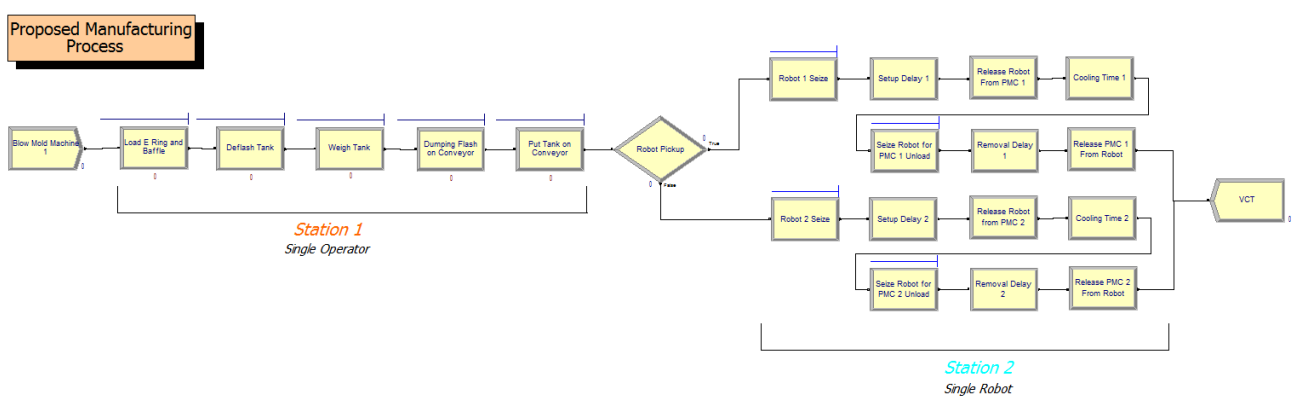

Figure 2: Proposed Manufacturing Process

Our redesigned line incorporates two stations as opposed to the one creating an ergonomically better workstation for the line operator by pushing all the hard manual labor into station two so that it can be completed by the robot. The challenge for this redesign was the logic implemented to split the robots seizes command between the two PMC lines. Initially we utilized logic that would split the line based on one already having a full queue, but by doing this we found that one PMC would receive all the gas tanks and the second was receiving none. This told us that the

utilization of the PMC was being underutilized so we made it a simple 50% split where each PMC grouping got an equal amount produced during the 8 hour shift. This also told us that the blow mold machine could be sped up in the current process or that an additional blow mold machine could be added. We saved this for later analysis.

We also acknowledged that the results of this simulation showed us a decline in output compared to the current process. We recognized that this should be the case. Since half the operator's workload has been taken away, his utilization should be halved. If the robot is faster in its job, times will exist where overlap happens, whereas with an operator it would not. This means that the cooling times will have variance and that overlap will decrease output. While this decrease in output may show that the proposed line is less efficient, our objective is to make the line more ergonomic for the worker which could be assigned to additional tasks now or operate two lines. For our purposes these results were acceptable to proceed on doing an analysis on further line advancements.

The plus side to knowing that the current simulation had processes that were underutilized was that we knew the fundamental weaknesses of the simulation and exactly where to target for improvement. The first area to attack was the underutilization in the system. To fix this we first decreased the cycle time of the blow mold machine and collected the results. The second solution was to see if the line could handle a second blow molding machine.

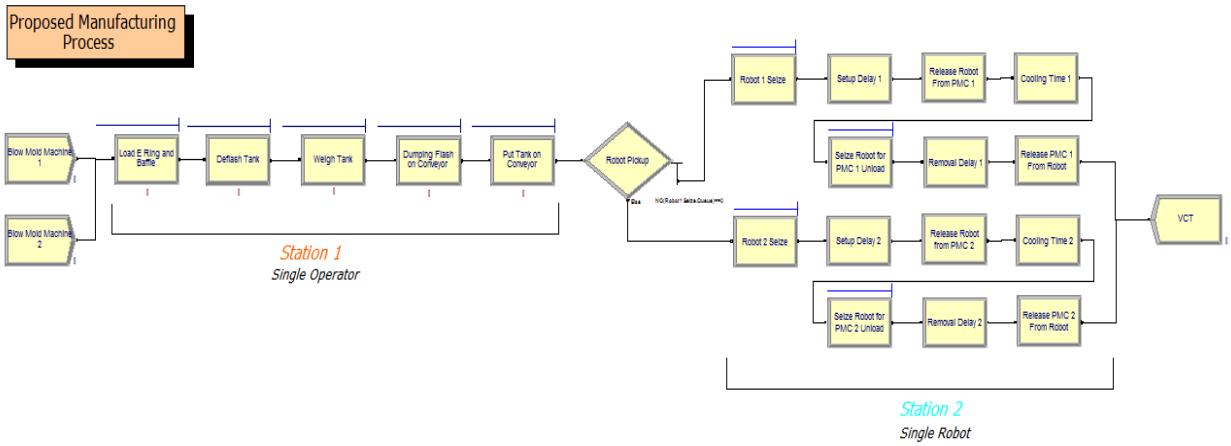

Figure 3: Proposed Manufacturing Process w/ Additional Blow Mold

Scheduled Utilization

	Value
PMC 1	0.9991
PMC 2	0.9954
Resource 1	0.6491
Robot 1	0.1535

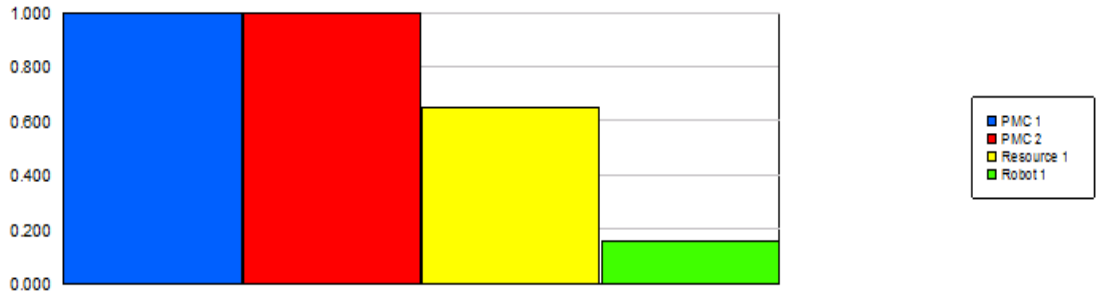

Figure 4: Utilization for PMC w/ ABM

What the utilization tells us is that both PMC's were fully utilized, but since this is the case we also saw bottlenecking at the second PMC machine grouping. What this told us was the additional blow mold machine added too many gas tanks into the system creating overutilization at station two of the model. The thought process was clear from here; add an additional PMC machine to establish the utilization and output. Below is the result of that simulation.

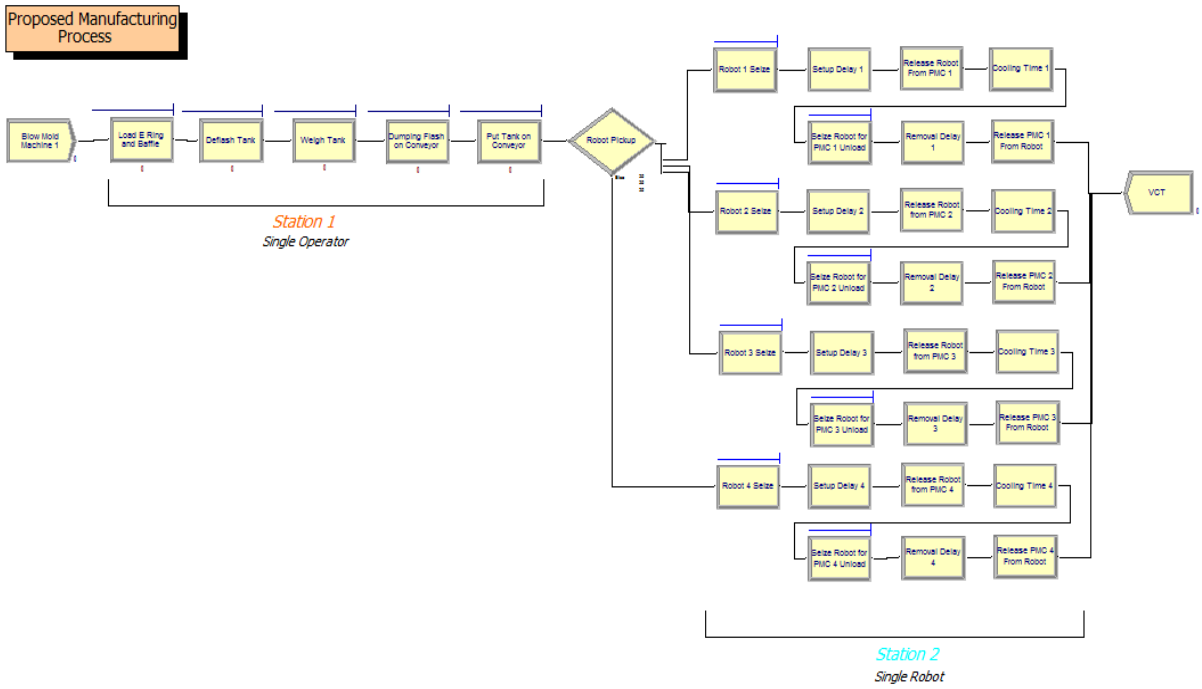

Figure 5: Proposed Manufacturing Process w/ additional four PMCs

It should be noted that we are not performing a full DOE for our line, but instead a sudo-DOE for the different scenarios. As such we did not want to change too many variables in the different iterations of the proposed process. The focus revolved around the following:

- Number of blow mold machines
- Robot Pickup logic
- Speed of the blow mold machine cycle time
- Amount of PMCs

When this simulation was run we once again saw underutilization by all the machines. This could be guessed before running the simulation as even with two PMCs it was underutilized, however to show comparison for later and compare with the basis the simulation was still created and run. When this simulation was run we once again saw underutilization by all the machines. This could be guessed before running the simulation as even with two PMCs it was underutilized, however to show comparison for later and compare with the basis the simulation was still created

and run. This realization brings us to our final model which is the obvious next evolution or the process, two blow mold machines to four PMCs.

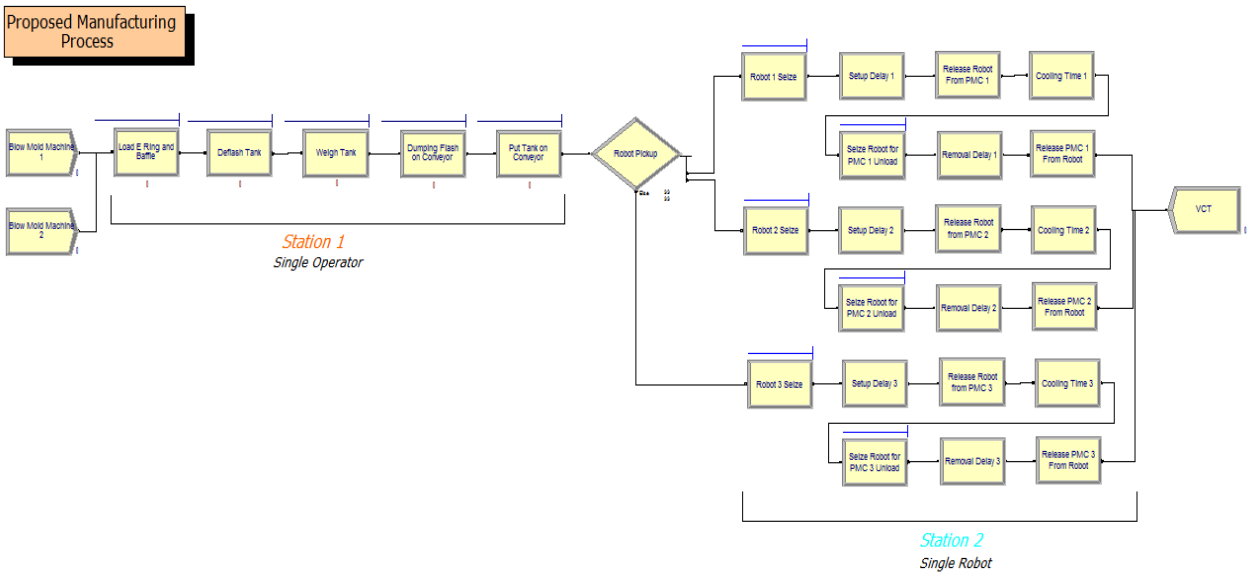

Figure 6: Process with two blow molds and four PMCs

This final simulation gave us the second highest output of all the different line variations as well as gave us a utilization we were looking for on the PMCs without causing sufficient bottlenecks for concern. Once this point was reached it was apparent that the scope of this project was achieved. Our final data set displays all of these for easy comparison; Table I.

6 Conclusions

After completing the first two objectives of this research paper and simulation model, we were able to analyze different scenarios on our PMC manufacturing line and determine if removing the human operator from the scenario and replacing it with a robot would have a positive effect, a negative effect, or no effect at all from a financial point of view. Obviously, there will be ergonomic benefits of replacing the human with a robot, but keep I mind the objective was to look at the financial impact of implementing such a system. What we found was that with our current system, there was no benefit to the system by adding a robot. The only way to make adding a robot to our system beneficial is if we spend additional company money on purchasing another 2 PMCs

and 2 Blow Molding machines which is pretty impractical. Further tests and mathematical equations would be needed to see if this purchase would benefit the company.

7 Future Works

Since this research paper only covered a portion of the plastic fuel tank manufacturing line, in the future our team would like to make a model of the line in its entirety with similar goals. Since the PMC simulation model had very little bottlenecks, we would be interested to see the bottlenecks that are occurring downstream in the line. For example, the testing and packaging area of the manufacturing line would be a good area to focus on since human operators are the key contributors of getting this work done.

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Appendix - A

Line Balance Analysis Sheet

Time available calculation	ASSY	MACH	MOLD
Customer requirement (parts/week)	5750.0	5750.0	5750.0
Work days per week	5	5	5
Shifts per day	3	3	3
Shift duration (Hrs)	8	8	8
Morning Meeting time per shift (Min)	0	0	0
Lunches and Breaks per shift (Min)	50	50	0
5S and TPM per shift (Min)	15	15	0
Average c/o time per shift (Min)	10	10	0
Total available time per week (sec)	364500.0	364500.0	432000.0
Planned Uptime (%)	90%	90%	1.0
Takt Time	3.391304347826087	3.391304347826087	5.130434782608700

Labor analysis	
Total productive work content (sec)	271.0
Total Direct Operators	5.0
Planned Direct Labor Min / Tank	.282608695652174
Value Add %	9854545454545455

Operator number	1	2	3	4	5	6	7	8	9	10	11	12
Operator Name Codes ®	OP 1	OP 2	OP 3	OP 4	OP 5	OP 6	OP 7	OP 8				
Number of operators working in parallel	1.0	1.0	1.0	0	0	0	1.0	1.0	0.0	0.0	0.0	0.0
Takt Time - Sec	75.13043478260870	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087	3.391304347826087
Target Rate - Sec	7.617391304347827	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477	0.052173913043477
Cycle Time - Sec	53.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
IN CYCLE ANALYSIS - SECONDS												
Work	35.0	28.0	55.0	53.0	33.0	30.0	37.0	0.0	0.0	0.0	0.0	0.0
Walk	16.0	9.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wait	2.0	6.0	0.0	0.0	10.0	20.0	15.0	0.0	0.0	0.0	0.0	0.0
Total Cycle time	53.0	43.0	55.0	53.0	53.0	50.0	52.0	0.0	0.0	0.0	0.0	0.0

Finishing							
Load tank next to rotary station	2	5.0	x				
Load ICV, E connector and (4) D- clips	2	20.0	x				
HSS bowl feeder							
Start Cycle	2	3.0	x				
Transfer and clamping	2	6.0			x		
Remove tank from F/c and slide to next station	2	6.0		x			
Stage next tank	2	3.0		x			
Assembly 1							
Move tank in to Station	3	3.0	x				
Install seal, MRA, Install Lock ring, Scan MRA and Lock	3	15.0	x				
Apply P label	3	4.0	x				
Break down MRA containers	3	8.0	x				
Install Recir line and tug test- Install wire harness and scan	3	10.0	x				
Move tank out of station	3	3.0	x				
Foam pad install table							
Move tank to station	3	3.0	x				
Apply Foam pads (3)	3	9.0	x				
Rotate and install Foam Pad(7)	4	30.0	x				
Move tank out of station	4	4.0	x				

Appendix–B:

Operator Elements		In Cycle					
WORK ELEMENT	Op #	cycle time	Work	Walk	Wait		
BMM							
Load E-Ring and Baffle on to the loading system	1	6.0	x				
Deflash Tank	1	6.0	x				
Weight tank and Apply T Label	1	4.0	x				
Walk to deflash	1	4.0		x			
Move flash to regrind conv	1	5.0	x				
Walk to PMC	1	5.0		x			
Move tank to PMC and start	1	4.0	x				
Walk to VCT	1	3.0		x			
Remove tank from PMC	1	5.0	x				
Load tank in VCT	1	5.0	x				
walk to Load station E ring and Baffle	1	4.0		x			
Restock time for Baffle 2 RC 120 changes per hr	1	2.0			x		

UPSIZING IN ORGANIZATIONS and INTER-ORGANIZATION AGREEMENTS

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ABSTRACT

Organizations that compete in their environment desire to upsize in order to improve and gain profit above average. Upsizing is considered a positive situation as it would provide more profit. Organizations can upsize not only in the industry they are in, but also in different industries. Upsizing can take two forms; management upsizing and financial growth. Upsizing ultimately would contribute to increase social wealth by providing benefits to shareholders, employees, clients, and society in terms of their expectations. In summary, organizations at all sizes can display upsizing behaviors in economy. The purpose of this review is to address important concepts to better understand effective upsizing.

Introduction

The components of an organization are categorized into two. This categorization includes qualitative and quantitative components. Elements such as culture, vision, politics, and management style in an organization are considered qualitative components. Improvements in the quality of these components are called qualitative upsizing. Substantial components that can be measured quantitatively such as sales income, product diversity, market share, financial structure are considered as quantitative components. Improvements in these components are called quantitative upsizing.

Upsizing ultimately would contribute to increase social wealth by providing benefits to shareholders, employees, clients, and society in terms of their expectations. Also, it is important to remember that the size of organizations and upsizing in organizations are two different concepts. Gibrat (1931) revealed that the size of organizations is not associated with upsizing. In summary, organizations at all sizes can display upsizing behaviors in economy.

1. Growth in Organizations

Book values, market values, total sales volume of organizations, total number of employees, sales volume, and other criteria can be used as a measure to identify the size of the organization. However, upsizing is defined as the change that's seen in these criteria within a certain timeframe (Baş, 1990: 47). Thus, upsizing refers to change and improvement.

The systems approach which developed after World War II considers organizations as a "whole" with their environments. According to this approach, organizations are a living organism. Just like other organisms, organizations are born, live and die (Immegart & Pılecki, 1973;30). This approach suggests that people need to adapt to their environment in order to continue their lives. This adaptation has brought the requirement of upsizing to organizations based on their structures. Change of important elements in environment such as technology, customer expectations and competitor organizations lead organizations to upsize. Organizations that have opportunities in alignment with their capacities should upsize as a result of rational decisions.

Many organizations that function globally today started as small organizations and became giants by upsizing. After the establishment of organizations, founders focus on how to upsize and improve them. This creates problems such as starting all over again at every phase (Clegg & Barrow, 1984;201). Although upsizing is key to obtaining high profits that carry organizations to success, it should be performed according to the resources and talents present. The goal of upsizing can sometimes be above average profit or it can be to be sustainable. Regardless of intentions, organizations which do not make progress would lose their marketshare in economic stagnation over time. Thus, upsizing is not only considered as an attack mechanism that comes with improvement, but also a defense mechanism. According to Petrof (1972), upsizing does not guarantee success but it is a concept that should definitely be addressed by organizations to sustain their existence.

As previously mentioned, reasons for upsizing can be categorised in multiple ways. Considering the organization's functions, main reasons are listed below:

- **Administrative reasons**. Organizations should be able to meet the expectations of customer and society, as well as identifying strategies that would get ahead of competitors in order to sustain their presence. Additionally, adaptation to environment has become a necessity for organizations. Upsizing provides important advantages for this main reason.
- **Production related reasons:** Increase in quality and production amount, decrease in unit cost during production, and particularly a desire to benefit from supply opportunities can lead organizations to upsize.
- **Financial reasons:** Factors such as gaining financial advantage in competition, efficient use of funds, and increasing profits provide a basis for upsizing.
- **Reasons related to market:** Desire to enter new markets, new marketing techniques, desired savings in sales expenses are among reasons for upsizing.

One other important aspect for organizations is to reach the most reasonable growth capacity with rational choices and certain strategies rather than random upsizing.

As can be seen, upsizing should be performed within a strategy. Greiner (1970) from Harvard University states that growth moves vary from one sector to another, however, this phase for smaller organizations consists of five phases that are; creativity, direction, delegation, coordination, and collaboration. These phases are not discussed in detail here as it is not within the scope of this section.

2. Growth Methods in Organizations

As previously mentioned, organizations tend to grow in general. Organizations choose a method depending on whether funds used for growth are met by internal or external means. Depending on the way these fund resources are used, growth is categorized in two ways, that are; internal growth and external growth. Organizations make a decision depending on their financial structures or the risks the growth type they want to perform involves.

2.1. Internal Growth

Intense competition conditions, rapidly changing technology and communication tools force organizations to grow. The financial resources of some organizations are sufficient to compensate the necessary growth through self-financing or loans. This type of growth is called internal growth. Capital, period incomes, or equalization reserves can cover the finances of internal growth. Internal growth is a method preferred by organizations that do not need big financing and that prefer a slow growth. Organizations can achieve internal growth in two ways: horizontal growth and vertical growth.

a- Horizontal Growth

Horizontal growth is the process of an organization's expanding its capacity to compensate its current products and market as well as manufacturing or functional activities (Ülgen & Mirze, 2010;209). It is the expansion of the scope of activities related to the same production field. A designer company whose headquarters is in Italy, opting to open branches in all European countries would be an example of horizontal growth. While horizontal growth is considered as entering different markets, it can also be considered as differences made in products.

Şimşek (2000) stated that horizontal growth would provide superior aspects to organizations such as expanding market share, having power in the market, strengthening of capital

and management structure that would result in better functioning and ultimately to take control of new organizations emerging in the production field. However, it also involves disadvantages such as increase of bureaucratic formalities, increase of management costs, prevention of efficient resource use due to removal of competition.

b- Vertical Growth

Vertical growth is a type of growth that embodies activities performed during consecutive processes of production in organizations. It stems from incorporating the supplier or the organization that provide necessary activities to complete a product. Vertical growth can be divided into two categories based on the type of activities: backward vertical integration and forward vertical integration.

Backward integration: Backward integration is a type of vertical growth (integration) referring to input that are use or production factors (Ülgen & Mirze, 2010;210). An example of backward integration would be a factory starting to produce eggs to be used in the biscuits produced in the factory. There are generally three reasons for backward integration for organizations. The first reason is not being able to produce a good quality input supply. The second reason is that suppliers provide significantly higher profit, and the third reason is that organizations have sufficient talent and resources to produce inputs.

Forward integration: In this type of growth (integration), organizations increase their activities to reach the ultimate product. If organizations have the talent and resources to be able to turn their products into their ultimate products, if they can provide their own distribution channels for less cost, or if the desired quality in distribution channels can't be achieved, then organizations might choose forward integration. An example of forward integration would be a farmer producing hay to feed his chickens with, to sell his chickens to make profit instead of selling his hay for a cheap price.

Additionally, an organization can prefer both forward and backward integration at the same time. The competition strategies of these companies are closely associated with their talents and resources.

2.2. External Growth

Sometimes organizations may prefer external growth due to financial resources or their risk policies. External growth can take place in the form of buying an organization, receiving its management or something similar. As this growth type provides important advantages particularly

in lack of resources, it is used frequently. Risks can be reduced based on the external growth type that would increase the speed of growth and reduce costs.

Moreover, organizations become partners with their competitors through this method and become more powerful. However, unlike internal integration, the external growth method would have to share its management with other organizations.

Horizontal external growth is defined as the integration of two or more organizations functioning in the same business field. Integration that take place with organizations that are in relation for input supply or ultimate product are called vertical external growth. If organizations integrate with other organizations in different industries, then these acts of integration would be called cross-fucntional integration. Integration that takes control of other organizations in the same market is called circular integration.

Trust, full integration, joint venture, strategic alliances, know-how, license agreements, franchising, agency and distributorships, using external resources, and build-operate-transfer are among the most frequently used external growth methods.

a- Trust

Trust organization is a type of integration that takes place through organizations being collected under one management. In this type of integration, organizations lose all their legal and economic entities and merge under a new legal structure. That is why this integration is not temporary but permanent. In markets that have trust organizations, monopolization happens in general. Many organizations integrate under one roof and monopolize the market. Exploiting clients through monopolization of these giants led to legal prevention of trust organizations in many countries.

b- Full Integration

Full integration takes place when big organizations buy small organizations. Full integration can take place in the form of backward vertical, forward vertical or horizontal. An organization can purchase its competitors, big or small, to increase its market share. However, in many countries, competition commissions ban horizontal full integration after a certain degree to prevent monopolization. With this method, the organization that is negotiated or bought loses its legal and economical existence.

Full integration sometimes takes place when backward or forward purchases are done within supply chains in organizations. Sometimes organizations may choose cross-growth with

full integration done in unrelated markets. The reasons for this include obtaining different income channels, using extra funding, etc. In this method which is actually known as merger or fusion (Tutar, 2015;16), a new organization does not emerge, and organizations lose their legal existence under the other's legal existence.

c- Joint Venture

Joint venture occurs through two or more parties creating a new enterprise (Mintzberg ve Quinn, 1995;307). While the organization's own legal identities remain the same, an organization or investment emerges with a new legal entity. Joint venture is particularly seen in foreign organizations entering a domestic market in which they jointly form an enterprise with a reliable and reputable organization. Organizations generally engage in shared investment due to reasons such as,

- Reducing the technology cost and high risk,
- Reducing costs in fixed investments,
- Desire to reach clients or distribution channels,
- Desire to learn another organization's technology
- Desire to enter a country that restricts foreigners from becoming organization owners (Ireland & Hitt, 1999;75, Naktiyok et al., 2009;127).

In addition to benefits that shared investments provide, there are also drawbacks such as profit sharing or technology transfer to another organization.

d- Strategic Collaboration

Combining two or more independent organizations' existence and skills to achieve a goal without establishing a new organization is called strategic collaboration (Das & Teng, 2003; 324). Similar reasons in joint investment requires strategic collaboration. In strategic collaboration, parties benefit as much as they contribute. Strategic collaborations differ among themselves based on the legal structure or methods.

Know-How is an integration that involves more technical collaborations. It is related to an experienced organization providing technical knowledge and consultance services to an organization that is less experienced. The organization receiving technical information uses the information in its own activities and pays a fee in return.

Licensing Agreements involves selling of production process, technique, brand and patents for a fee (Can Mutlu, 2008;105). This way, the licensing organization produces its products in regions they haven't reached yet, while reducing risks and costs. Licensee can use the brand of the organization, open stores, and conduct activities in its region depending on the agreement. In return, licensee pays a fee to the licenser.

Franchising is the permission given to sell the products or services of an organization in a certain location (Cowie, 1990;400). This is an effective way of reaching consumers and growing rapidly. Franchisee's legal and economical structure is independent, however, due to the agreement made, franchisee performs the franchiser's activities by representing the franchiser for a certain period of time. As the franchiser's name is used, the franchiser desires to protect its quality standards. Franchisers should develop organization control mechanisms well and monitor whether the franchisee functions within the standards. Otherwise, the franchiser may lose its reputation. Although the franchiser transfers its organization representation authority and the right to use marketing program, it is involved in selection of personnel, training and the design of the location where services will be provided to protect its quality standards.

Agency and Distributorships are collaborations resulting from using other organizations for distribution channels within the supply chain. The main organization collaborates with other local organizations to deliver its activities to consumers. There are legal regulations for agency rules in the Turkish Trade Law.

e- Outsourcing

One other form of external growth is outsourcing. Outsourcing is a collaboration between different organizations producing in different facilities while conductinig this production in a way that compensates each other. However, this way of production is not for single or multiple times but constant (Koçel, 2011; 384). In fact, this approach occurs by organizations performing activities by implementing their own fundamental skills and having other organizations perform activities that they don't have the skills for.

According to Barney, the main talent of an organization should not be easily imitated or replaced, to be rare and valuable. Thus, organizations should carry talents that are related to the organization's main function and increase its competitive advantage.

This approach allows organizations to reduce costs and constantly improve their core skills by focusing on what they know the best.

f- Build-Operate-Transfer

This approach involves countries achieving the investments they need related to their infrastructure through private sector. Organizations grow, provide income, and transfer the investment to the public after a certain time by using the country's resources.

Particularly in big projects, public institutions with limited finances turn their resources into investments. Sometimes this takes place through one organization and sometimes through consortium. This is a common investment method in Turkey and it contributes to the growth of organizations in the private sector.

3. Agreements between Organizations

As discussed previously, organizations usually engage in either internal or external growth. In some situations, they protect each other's benefits through mutual agreements and try to receive competitive advantage. As some of the agreements between organizations are discussed in the section on external growth, they won't be addressed in this section.

3.1. Cartel

Organizations with similar products and services come to an agreement and merge to determine the prices, to limit the production volume, to share the market, and ultimately to monopolize. This structure is called cartel (Şimşek, 2000;72). In these types of agreements, the legal and economical structure is not lost and the purpose is to protect the interests of organizations. These are temporary agreements and geared towards eliminating competition.

Cartels occur in the form of confidential agreements due to its prohibition in many countries and not being ethical. Organizations that do not obey the determined price policies or quotas receive penal sanction in accordance with the agreemnet.

3.2. Consortium

Consortium occurs by the merger of financial and technical opportunities of domestic or international organizations in the same sector or in different expertise fields to win a tender in contracting (Mucuk, 2003;49). The purpose is to be stronger in financial and technical aspects. Being stronger increases profitability and gains competitive advantage. The most important distinction from a joint venture is not having the requirement to form an establishment under a new legal structure.

The organization of a consortium which is mostly seen in national or international organizations can be domestic or international. The main purpose is to combine expertise and resources. In our country, consortiums are seen mostly in construction business. In these consortiums, national and international organizations accomplished many construction projects by combining their strengths such as equipment pool, expertise, financial resources, and human capital.

3.3. Holding

Holdings are established within certain legal regulations unlike cartels and trusts. In holdings, the main organization owns other organizations' shares and therefore monitor and guide them. A main organization becomes a parner in management of other organizations by owning their shares and receives the right to monitor them. All the companies under the main organization have their own legal entities.

Generally, when more than one organization functions in family organizations, holdings are preferred to monitor the financial structure from one hand, to provide the same trust of the name in all organizations, and meeting needs such as management and monitoring from one structure. Due to these superior characteristics, holdings are preferred not only by family organizations but other organizations as well. However, sometimes holding organizations buy other organizations' shares which reduces effectiveness.

3.4. Employers' Associations

Chambers organize to protect their profit possibilities and professional interests (Şimşek, 2000;75). These organizations are employer unions and professional associations. Association of Chambers of Commerce and Industry, Chambers of Merchants and Craftsmen, Turkish Employers' Syndicates, Independent Industrialist and Businessmen's Association, Turkish Industry and Business Association are examples of employers' associations.

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