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The Impact of Total Quality Management on Organizational Innovation

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ABSTRACT

Many organizations are facing competitive challenges due to the rapid pace of technological change. Management theorists and practitioners alike have called for more creativity and innovation in product lines, management practices and production processes. On one hand, Total quality management (TQM) has long been a major management practice. Recognition of TQM as a competitive advantage is widespread around the world, and few companies can afford to ignore TQM.

Therefore the purpose of this paper is to identify and extraction TQM & Innovation dimensions. In first part have been recognized four dimensions for TQM and two dimensions of Innovation, The four TQM dimensions in this study include Leadership, Employee relations, Customer focus , Continuous improvement and the two Innovation dimensions are Product innovation and Process innovation. Also, in this paper used a DEMATEL Method to examining the Causal relations these factors.

Inattention to results, the most influential factor is Leadership and more affected factor is Process innovation. As a result Leadership has more influence on Innovation.

1. Introduction

The introduction of total quality management (TQM) has played an important role in the development of contemporary management practices. Quality is considered as a key strategic factor in achieving business success. In order to enhance the competitive position and improve business performance, companies worldwide, large and small, manufacturing and service, have applied the principles of total quality [1]. Also, Total quality management (TQM) has been regarded as one of the most predominant sources of competitive advantage in the last two decades. Numerous studies have shown a positive relationship between TQM and organizational performance [2]. The critical factors of TQM can be described as best practices or ways in which “firms and their employees undertake business activities in all key processes: leadership, planning, customers, suppliers, community relations, production and supply of products and services, and the use of benchmarking [3]. TQM encompasses and facilitates all functional areas, processes, and systems of businesses, including design, development, production, distribution, and customer support. This holistic approach aims to maximize customer satisfaction based upon incessant endeavors for innovation and

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advancement [4]. On one hand Innovation is a core renewal process within organizations and a cornerstone of competitive strategy. It is defined as the development and implementation of a new idea, be it a new technology, product, organizational process, or arrangement. [5] Innovation is a main strategic tool to have a competitive advantage in such complex environments and it is a necessity for long-term success, growth, sustainable performance, and to survive as the firm's industry. For this reason, firms accept that innovation is a strategic necessity, not a strategic choice, and innovation is generally introduced as the key factor for competition in various markets [6].

Therefore this paper identifies and extraction TQM & Innovation dimensions then examining Causal relationship TQM & Innovation with DEMATEL (Decision Making Trial and Evaluation Laboratory) method.

2. Literature Review

2.1.Total quality management

TQM comprises a group of ideas and techniques for enhancing competitive performance by improving the quality of products and processes' TQM is a company-wide philosophy of quality improvement. This philosophy contends that the firm's primary goal is to meet customer requirements better by improving the quality of products and processes [7]. Also, TQM is a management process and a set of disciplines that are co-ordinated to ensure that the organization consistently meets and exceeds customer requirements. TQM engages all divisions, departments and levels of the organization. Senior management organizes all of its strategy and operations around customer needs and develops a culture with high employee participation. Companies with TQM are focused on the systematic management of data in all processes and practices to eliminate waste, and pursue continuous improvement [8]. And it has been implemented in many countries over the world to improve organizational performance in areas such as increasing profits, productivity and market share [9].

2.1.1. TQM practices

11 TQM practices are given below:

management commitment, the role of the quality department, training and education, employee involvement, continuous improvement, supplier partnership, product/service design, quality policies, quality [10]. In this study, TQM practices include Leadership, Customer focus, and Continuous improvement and Employee relations.

1-Leadership: Employees' performance enhancement is determined by top management's guidance with concrete and feasible vision. Top managements' leadership capabilities not only affect TQM implementation but also improve other organizational activities [4]. 2-Employee relations: In order to effectively participate in quality management, employees need to be adequately trained and explained about the benefits of the TQM practice. Management must ensure an organization-wide training program. Employee satisfaction and fulfillment in terms of benefit and compensation, together with better teamwork, may lead to

better performance [11]. 3-Customer focus: Customer focus, which is the most important part of production, means producing and delivering products and services that fulfill customers' present and future needs and expectations. Customer focus also refers to exceeding customers' expectations in order to ensure long-term organizational success and survival [12]. 4-Continuous improvement: Continuous improvement is the philosophy of improvement initiatives that increases success and reduces failure. Das et al. [13] defined continuous improvement as a company-wide process of focused and continuous incremental innovation. For continuous improvement, evaluation of current processes and quality management practices is necessary. Continuous improvement refers to searching for never-ending improvements and developing processes to find better methods in the process of converting inputs into outputs. By improving interlinked processes, a firm can do a better job of satisfying customers' needs and expectations [12].

2.1.2. Innovation

Samat et al. [10] suggested that innovation is equated with the adoption and application of new knowledge and practices, including the ability of an organization to adopt or create new ideas and implement these ideas in developing new and improved products, services, and work processes and procedures. Innovation, then, is considered an intangible resource that is very difficult to imitate. Such resources constitute an organizational capital, a source of competitive advantage. In the OECD Gunday et al. [14], four different innovation types are introduced. These are product innovation, process innovation, marketing innovation and organizational innovation. Product and process innovations are closely related to the concept of technological developments. In this study, Innovation types include Product and process innovations.

1-Product innovation: It is the development and introduction of a new product to the market or the modification of existing products in terms of function, quality consistency, or appearance 2- Process innovation: It involves creating and improving the method of production, and the adoption of new elements (e.g. Input materials, task specifications, information flow, and equipment) to the firm's production process [15].

3. TQM & Innovation relationship

In the past two decades, several scholars have claimed the positive relationship between TQM and innovation. The dimensions of TQM can assist an organization in creating a more innovative culture. Hence, TQM is not a hindrance towards innovation in providing new products, services, and processes, as new and improved methods can be used to attain more efficient and effective businesses [16]. Also, there are many common aspects of TQM and innovation. They both emerged as partial answers to the intense competitive pressure that manufacturing sector organizations are facing. Some elements of TQM and innovation are similar. For example, continuous improvement is a key feature of both TQM and innovation [17].

Therefore, in attention to the important role of TQM and Innovation in the Firm's performance, at first this paper examines the effect of Total quality management on Innovation Then examines the causal relations of TQM and Innovation dimensions with DEMATEL method.

4. Research method

In this section, the steps of work performance are explained (Figure 1).

After identifying and extraction TQM& Innovation dimensions, a questionnaire was planned to determine the interdependence between the factors. Therefore used by the DEMATEL technique to assess Causal relationship and the effects of factors to each other.

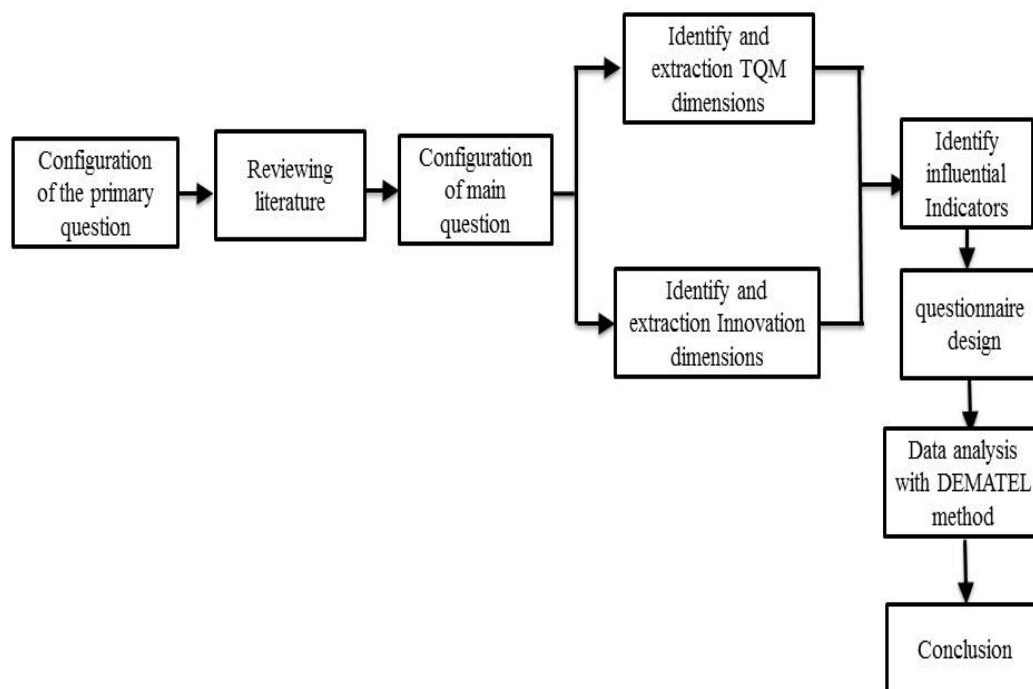


Figure1.Research method

5. Methodology

The DEMATEL method, developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976, can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system .The DEMATEL, used to research and solve complicated and intertwined problems, has been successfully applied in many situations, such as marketing strategies, R&D project, e-learning evaluation, managers' competencies, control systems and airline safety problems [18].

5.1.DEMATEL steps

Step 1: Generating the direct-relation matrix. We use four scales for measuring the relationship among different criteria: 0 (no influence), 1 (low influence), 2 (high influence),

and 3 (very high influence). Next, decision makers prepare sets of the pairwise comparisons in terms of effects and direction between criteria. Then the initial data can be obtained as the direct-relation matrix which is an $n \times n$ matrix A where each element of a_{ij} is denoted as the degree in which the criterion i affects the criterion j .

Step 2: Normalizing the direct-relation matrix. Normalization is performed using the following,

$$X = K \cdot A \quad (1)$$

$$k = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}}, \quad i, j = 1, 2, \dots, n \quad (2)$$

Step 3: Attaining the total-relation matrix. Once the normalized direct-relation matrix X is obtained, the total relation matrix T can be acquired by using Equation (3), where I is denoted as the identity matrix

$$T = X(1 - X)^{-1} \quad (3)$$

Step 4: Producing a causal diagram. The sum of rows and the sum of columns are separately denoted as vector D and vector R through Equations (4-6). Then, the horizontal axis vector $(D + R)$ named ‘‘Prominence’’ is made by adding D to R , which reveals the relative importance of each criterion. Similarly, the vertical axis $(D - R)$ named ‘‘Relation’’ is made by subtracting D from R , which may divide criteria into a cause and effect groups. Generally, when $(D - R)$ is positive, the criterion belongs to the cause group and when the $(D - R)$ is negative, the criterion represents the effect group. Therefore, the causal diagram can be obtained by mapping the dataset of the $(D + R, D - R)$, providing some insight for making decisions.

$$T = [t_{ij}]_{n \times n}, \quad i, j = 1, 2, \dots, n \quad (4)$$

$$D = \left[\sum_{j=1}^n t_{ij} \right]_{n \times 1} = [t_{i.}]_{n \times 1} \quad (5)$$

$$R = \left[\sum_{j=1}^n t_{ij} \right]_{1 \times n} = [t_{.j}]_{1 \times n} \quad (6)$$

where vector D and vector R , respectively denote the sum of rows and the sum of columns from total relation matrix $T = [t_{ij}]_{n \times n}$.

Step 5: Obtaining the inner dependence matrix. In this step, the sum of each column in the total-relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired [19].

6. Proposed model

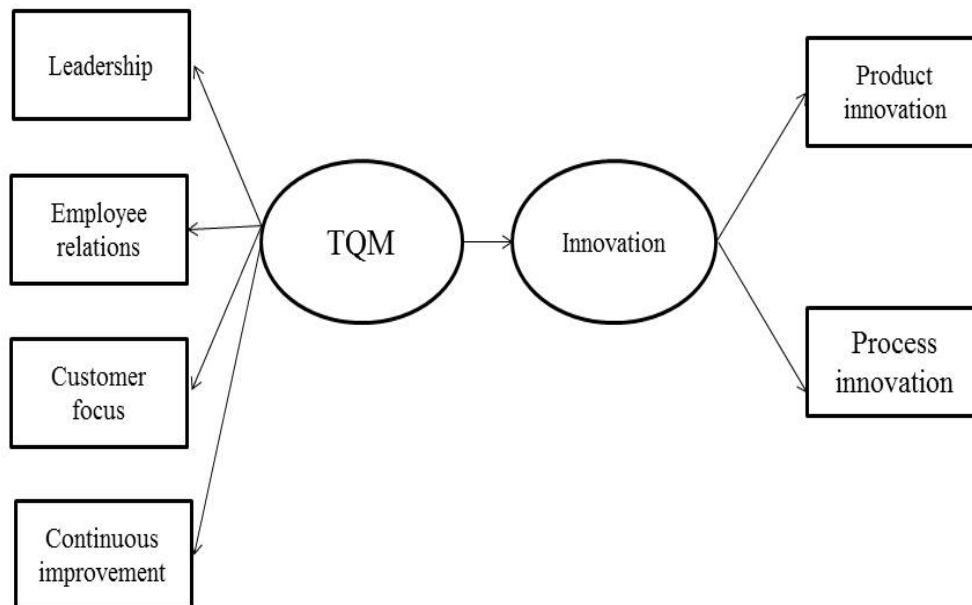


Figure2. The proposed model

7. Results

Table 1. Geometric average of Questionnaire's elements

	Leadership	Employee relations	Customer focus	Continuous improvement	Product innovation	Process innovation
Leadership	0.00	3.1	1.5	3.9	2.5	1.9
Employee relations	2.4	0.00	2.6	3.8	2.5	2.1
Customer focus	2.1	2.9	0.00	1.9	3.8	3.1
Continuous improvement	1.9	2.5	2.7	0.00	3.1	3.6
Product innovation	2.7	2.1	3.8	1.7	0.00	3.8
Process innovation	2.1	1.8	3.1	2.1	3.7	0.00

Table 2. The normalized direct-relation matrix

	Leadership	Employee relations	Customer focus	Continuous improvement	Product innovation	Process innovation
Leadership	0.00	0.22	0.10	0.27	0.17	0.13
Employee relations	0.17	0.00	0.18	0.27	0.17	0.15
Customer focus	0.15	0.20	0.00	0.13	0.27	0.25
Continuous improvement	0.13	0.17	0.19	0.00	0.22	0.25
Product innovation	0.19	0.15	0.27	0.12	0.00	0.27
Process innovation	0.15	0.13	0.22	0.15	0.26	0.00

Table 3. Direct and Indirect (total) - Relationship Matrix

	Leadership	Employee relations	Customer focus	Continuous improvement	Product innovation	Process innovation
Leadership	2.54	2.91	3.17	3.10	3.54	3.42
Employee relations	2.81	2.87	3.39	3.23	3.72	3.60
Customer focus	2.95	3.19	3.41	3.29	3.97	3.87
Continuous improvement	2.84	3.07	3.46	3.06	3.81	3.75
Product innovation	2.97	3.15	3.62	3.28	3.76	3.87
Process innovation	2.74	2.92	3.34	3.07	3.70	3.40

Table4. The sum of influences given and received on criteria

	R		D		D+R		D-R
Product innovation	22.50	Customer focus	20.69	Product innovation	43.13	Leadership	1.84
Process innovation	21.92	Product innovation	20.64	Process innovation	41.08	Employee relations	1.51
Customer focus	20.39	Continuous improvement	19.99	Customer focus	41.08	Continuous improvement	0.97
Continuous improvement	19.02	Employee relations	19.62	Continuous improvement	39.01	Customer focus	0.30
Employee relations	18.11	Process innovation	19.16	Employee relations	37.73	Product innovation	-1.86
Leadership	16.85	Leadership	18.68	Leadership	35.53	Process innovation	-2.75

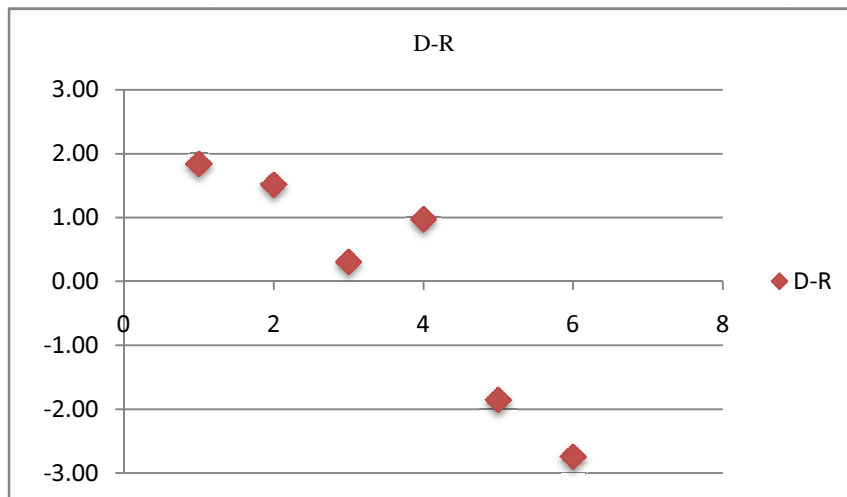


Figure 3. The priority of the factors on the basis of effective severity

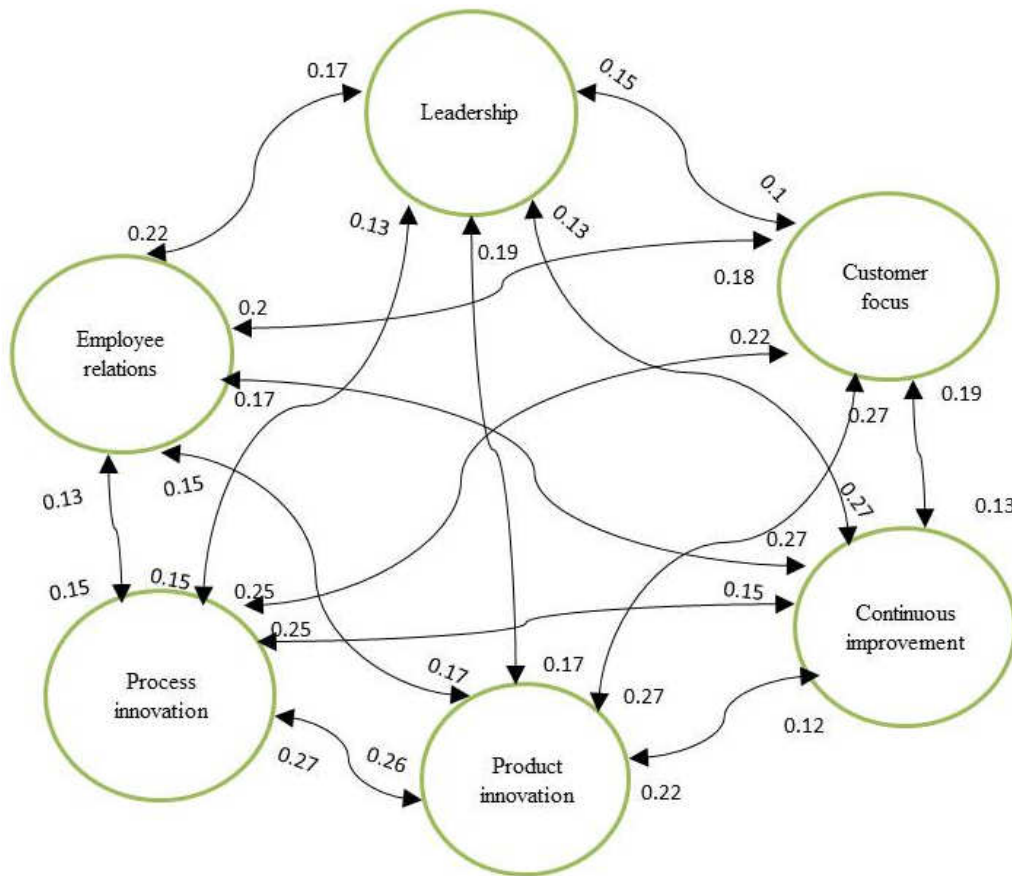


Figure 4. Relative severity of direct and indirect relations algorithms

8. Conclusions

Total quality management (TQM) is a business management strategy seeking to improve the quality of organizational management, and hence, can improve the competitiveness and value provided to customers. TQM provides a competitive edge for companies. Also, the current relationship between TQM in innovation performance and company performance have been established, research on the relationship between TQM practices and product innovation performance has not been conducted in detail. In this study a questionnaire has designed on the basis TQM & Innovation dimensions. Finally, the results of questionnaires were analyzed on the basis of DEMATEL technique. TQM included Leadership, Employee relations, Customer focus, Continuous improvement and the Innovation included Product innovation and Process innovation. According to the results, among the four criteria for TQM, Leadership is the most direct effectiveness. Also, among the two criteria for innovation process innovation is the most affected factor.

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Estimating Duration of Projects Manual Tasks Using MODAPTS plus Method

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ABSTRACT

Estimating duration of projects manual tasks is one of the crucial concepts and problems of their management and control. Methods have been used to achieve this estimation are so difficult, time consumer and basically unreliable. In this paper a new method is introduced based on modular arrangement of predetermined time standards (MODAPTS) plus method which is the well-known method of work measurement. The method is reliable according to reliability of the MODAPTS method. The method is so easy to use, so quick in application, has rapid derivation of objective standards and its analysis are regarding people and their capacities. Finally, an applicability of the method is illustrated by some general manual sample civil works and the results are shown at the end of the paper.

1. Introduction

A project is a sequence of unique, complex, and connected activities with one goal that must be completed by a specific time, quality and budget [1]. Every project is made up of steps that must be accomplished in order for the project to be finished. Schedule, cost and quality as the three traditional main criteria, directly affect project and its success [2, 3]. So, one of the most important steps in any project is its scheduling that takes the previously determined project activities and puts them into a proper timetable. The scheduling directly depends on accuracy of the activities time estimations [4, 5, 6]. Activity duration is the time between the start and finish of a schedule activity. Once you know this number, you can prioritize or plan accordingly to meet your needs. However, the task duration is a key input for project scheduling [7]; it has received little attention because of its difficulty to estimate [8]. Scholars such as King and Wilson [9], Smith and Mandakovic [10], Hendrickson et al., Arsham [11], Mohan et al. [6], and Shankar and Siresha [8] proposed their model in order to estimate the tasks duration [7]. One of the most regular methods which is used to estimate the activity times is project evaluation and review technique (PERT) presented by Malcolm et al. [12]. The basic method is established on beta probability density function but some researchers introduce their approaches as shown in Table 1. However the different approach of the PERT are useful but they have some weaknesses. They are in law mathematical creditability [13, 14] and based on the experts points which fail to provide an objective and quantitative

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analysis [4, 15]. They are expensive, time consuming and complex to install [16] and they have so much assumptions to achieve time estimation [17, 18]. The reliability of the estimation depends how closely the project correlates with past experience and the ability of the expert to recall all the facts of the project [4]. In this paper a new method is proposed to obtain estimation in the case of manual tasks durations using MODAPTS method as a well-known time study tools. The method is not only simple, flexible and comprehensive in comparison with the other methods, but it is fundamentally reliable according to reliability of the MODAPTS method. It is not necessary to have expert's points about task duration and it is the other advantages of the method according to its time saving property. The rest of this paper organized as follows. Section 2 describes the model in detail, in section 3, simulation details and results are explained and finally, section 4 concludes the paper.

Table 1. Different approach of PERT

No.	Method	Mean	Variance
1	Malcolm et al. [12]	$x_{0.0} + 4x_m + x_{1.0}/6$	$(x_{0.0} - x_{1.0}/6)^2$
2	Perry and Greig [19]	$x_{0.05} + 0.95x_m + x_{0.95}/2.95$	$(x_{0.95} - x_{0.05}/3.20)^2$
3	Pearson and Tukey [20]	$0.63x_{0.50} + 0.185[x_{0.05} + x_{0.95}]$	$0.63(x_{0.50} - \hat{\mu})^2 + 0.185[(x_{0.05} - \hat{\mu})^2 + (x_{0.95} - \hat{\mu})^2]$
4	Moder and Rodgers [21]	$x_{0.05} + 4x_m + x_{0.95}/6$	$(x_{0.95} - x_{0.05}/3.20)^2$
5	Davidson and Cooper [22]	$x_{0.10} + 2x_m + x_{0.90}/4$	$(x_{0.90} - x_{0.10}/2.65)^2$
6	Swanson in Megill [23]	$0.40x_{0.50} + 0.30[x_{0.10} + x_{0.90}]$	$0.3(x_{0.50} - \hat{\mu})^2 + 0.4[(x_{0.10} - \hat{\mu})^2 + (x_{0.90} - \hat{\mu})^2]$
7	Farnum and Stanton [17]	$\begin{cases} \frac{2}{(2 + 1/x_m)}, & x_m \leq 0.13 \\ \frac{(36x_m^2 + 1)(1 - x_m)}{(36x_m + 1)(1 - x_m) + x_m}, & \text{others} \end{cases}$	$\begin{cases} \frac{x_m^2(1 - x_m)}{(1 + x_m)}, & x_m \leq 0.13 \\ \frac{(x_{0.0} - x_{1.0})^2}{6}, & \text{others} \end{cases}$
8	Ginzburg [24]	$2x_{0.0} + 9x_m + 2x_{1.0}/13$	$\frac{(x_{1.0} - x_{0.0})^2}{1268} \left[22 + 81 \frac{x_m - x_{0.0}}{x_{1.0} - x_{0.0}} - 81 \left(\frac{x_m - x_{0.0}}{x_{1.0} - x_{0.0}} \right)^2 \right]$
9	Cottrell [25]	x_m	$(x_{1.0} - x_m)/3.44$
10	Premachandra [18]	$\frac{36x_m^2(1 - x_m) + 1}{36x_m(1 - x_m) + 2}$	$(x_{0.0} - x_{1.0}/6)^2$
11	Mohan et al.[6]	$\log(x_{0.0}) + 3.44var(x)$ or $\log(x_{1.0}) - 3.44var(x)$	$1.72 - \left[2.9584 + \log \left(\frac{x_{0.0}}{x_m} \right) \right]^{1/2}$ or $-1.72 + \left[2.9584 + \log \left(\frac{x_{1.0}}{x_m} \right) \right]^{1/2}$
12	Shankar and Siresha [26]	$5x_{0.0} + 17x_m + 5x_{1.0}/27$	$(x_{0.0} - x_{1.0})^2/35$

x_p : The p-fractile of the random variable X x_m : The mode of the random variable X

2. The MODAPTS method

Since 1909, stopwatch time study and predetermined time standards have been utilized by engineers [27]. Work measurement traditionally has been used to determine reasonable time for a people to carry out the task; reasonable amount of output per worker and the efficient method for the person doing the task. A predetermined motion time standard system (PMTS) as an advanced work measurement technique is utilized to establish standard data for basic human motions (work elements) to estimate performance time of workers [28-30].

A PMTS requires that the analyst break apart the process into its component actions, assign time values to each action, and sum the times to calculate the total standard time. MODAPTS, as a PMTS method, was introduced in 1966 by G.C.C. Heyde who learned the MTM-1 and MTM-2 methods in the 1950s and sought a simpler technique to use and apply. The benefits of the MODAPTS technique are: (1) easy and fast to apply, (2) accurate and reliable results, (3) communication and productivity improvement, (4) quick rates determinations, (5) quantitative basis of the method, (6) ergonomic improvement, (7) increasing in utilization of labor individual management [31,32].

Unlike the MOST and MTM standards, it uses a MOD as the basis for measurement. The other versions of the method are: office MODAPTS in 1969, transit MODAPTS and workability [33], MODAPTS plus [32] and repertory and profiles of work [31]. The elements in MODAPTS Plus [31, 32] which are shown in Figure 1 cover closely all of the physical activities of workers, each of which has a unique code in two parts like Basic-MOST, MODAPTS. The first is alphabetic which indicates the body part involved and the other component is numeric which indicates the MOD's charged to the activity when multiplied by 129milliseconds.

3. Proposed method, using empirical study

According to the predetermined structure of the MODAPTS method, it can be used to estimate duration of manual tasks in projects which is the difficulty of the project management and control. Duration of projects machine works can be easily and successfully estimated by the capacity of the machines used in that works. In Table 2 we select eight real general tasks-as a sample of the projects general manual tasks-and estimate their duration using MODAPTS plus. The estimated duration of these tasks are shown in last column of the table.

In order to show the applicability and reliability of the method, a comparison is done between the results illustrated in Table 2 and the results given by some demonstrated methods which are introduced in Table 1. To simplify the comparison, only the methods which are using 3 points are given and some experts are asked to have these three points estimation. The tasks which are asked are the tasks which are considered in the proposed method with the same work volume. The work volumes and the three point estimations which are shown in Table 3 -optimistic, pessimistic and probable times- are estimated by simple average of 10 experts points.

Now the results are compared with the results of other predefined methods, using the analysis of variance (ANOVA) method. Because the number of the activities are smaller than 30, the T-test is applied and the results are shown in Table 5. One can see that the results of the proposed method are acceptable in comparison with the other predefined methods. In addition, the kendall and Peaerson correlation coefficients are shown in Table 6. It is obvious that the correlation coefficients between the proposed method and some of the predefined methods are very good. So the applicability and reliability of the method is demonstrated.

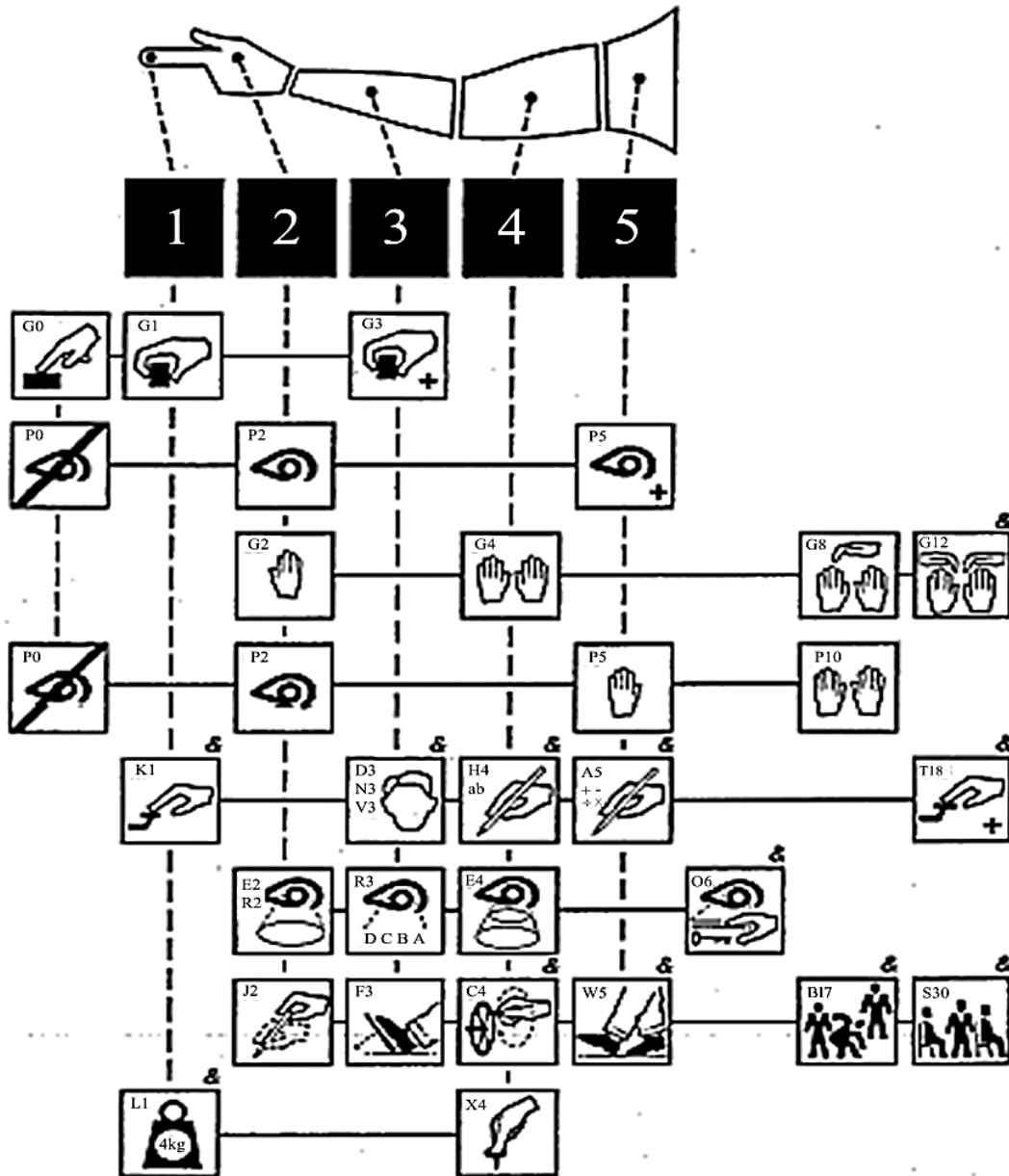


Figure 1: Elements of MODAPTS plus method

4. Results and conclusion

In this paper the new method is introduced to estimate duration of tasks in projects. The method uses MODAPTS method to define tasks duration and the results show its applicability. The superiority of the method is its simplicity and its quickness in comparison

with the other methods. The other advantage of the method is its able to do without experts points and so its reliability is increased. The inclusiveness of the method which makes it able to work with any handy tasks is its other superiority.

Table 2: Eight general manual tasks duration

No.	Task description	MOD formula	Frequency	Time
1	Manual cut	M4G2M4U1	835	1.645646
2	Ceramic works	W5G4P2G2U2G8M3J2G2U3	250	1.478125
3	Granit work for stairs face	M2G2W5P0M3G2 4M4 4U3G4W5P2 4M2 4G2 4U1 4M3 4P0	153	2.275238
4	Tail works	M7G2P5M4G2M4P0W5M2G2U1M3P0	700	4.640417
5	Mosaic works	W5G2P2G2U2G8M3J2G2U3M2G2U3	1050	5.831875
6	Block works	W5G4W5P2W5.5	2000	13.61667
7	Insulation by tar	M2U3G2P2G4W5C4M4P0M2G1P5	202	1.230517
8	Painting	5(M2G2M3P0M3J2U3)/1m ²	200	2.687500

Table 3: Eight general manual tasks duration three points estimations

No.	Task description	Frequency	Time		
			Optimistic	Probable	Pessimistic
1	Manual cut	200m ³	1.5	1.52	1.6
2	Ceramic works	40m ²	1.15	1.44	1.73
3	Granit work for stairs face	15m ²	1.8	2.27	2.72
4	Tail works	42m ²	3.57	4.464	5.357
5	Mosaic works	168m ²	4.5	5.625	6.75
6	Block works	200m ²	10	12.5	15
7	Insulation by tar	100m ²	1	1.25	1.5
8	Painting	100m ²	2	2.5	3

Table 4: Eight general manual tasks duration estimation

		Method Number					
		1	3	6	7	8	10
Task Number	1	$\sigma=0.0208$ $\mu=1.5625$	$\sigma=0.0431$ $\mu=1.5925$	$\sigma=0.0407$ $\mu=1.785$	$\sigma=0.0208$ $\mu=1.635$	$\sigma=0.0605$ $\mu=1.625$	$\sigma=0.0208$ $\mu=1.635$
		μ					
	2	$\sigma=0.0481$ $\mu=1.44$	$\sigma=0.3605$ $\mu=1.44$	$\sigma=0.2142$ $\mu=1.375$	$\sigma=0.0481$ $\mu=1.532$	$\sigma=0.0481$ $\mu=1.442$	$\sigma=0.0481$ $\mu=1.626$
	3	$\sigma=0.0758$ $\mu=2.272$	$\sigma=0.568$ $\mu=2.272$	$\sigma=0.2925$ $\mu=2.5$	$\sigma=0.0758$ $\mu=2.415$	$\sigma=0.0758$ $\mu=2.272$	$\sigma=0.0758$ $\mu=2.563$
	4	$\sigma=0.1489$ $\mu=4.465$	$\sigma=1.116$ $\mu=4.465$	$\sigma=0.5746$ $\mu=4.91$	$\sigma=0.1489$ $\mu=4.465$	$\sigma=0.1489$ $\mu=4.465$	$\sigma=0.1489$ $\mu=5.036$
	5	$\sigma=0.1877$ $\mu=5.625$	$\sigma=0.3125$ $\mu=5.625$	$\sigma=0.1609$ $\mu=6.075$	$\sigma=0.1877$ $\mu=5.975$	$\sigma=0.1877$ $\mu=5.625$	$\sigma=0.1877$ $\mu=6.34$
	6	$\sigma=0.417$ $\mu=12.5$	$\sigma=3.125$ $\mu=12.5$	$\sigma=1.609$ $\mu=13.75$	$\sigma=0.417$ $\mu=13.278$	$\sigma=0.417$ $\mu=12.5$	$\sigma=0.417$ $\mu=14.1$
	7	$\sigma=0.0417$ $\mu=1.25$	$\sigma=0.3125$ $\mu=1.25$	$\sigma=0.1609$ $\mu=1.375$	$\sigma=0.0417$ $\mu=1.3278$	$\sigma=0.0417$ $\mu=1.25$	$\sigma=0.0417$ $\mu=1.41$
8	$\sigma=0.0834$ $\mu=2.5$	$\sigma=0.625$ $\mu=2.5$	$\sigma=0.3218$ $\mu=2.75$	$\sigma=0.0834$ $\mu=2.655$	$\sigma=0.0834$ $\mu=2.5$	$\sigma=0.0834$ $\mu=2.82$	

Table 5: The results of ANOVA

	Method Number					
	Proposed Vs. Method1	Proposed Vs. Method3	Proposed Vs. Method6	Proposed Vs. Method7	Proposed Vs. Method8	Proposed Vs. Method10
$\{H_0: \mu_{proposed} = \mu_{other}$ $H_1: \mu_{proposed} \neq \mu_{other}$						
T-value	0.959761	0.048048	-0.07562	-0.04344	0.077522	-0.05772
$t_{0.05,7}$	1.895		$-t_{0.05,7}$		1.895-	
Comparison	$T \leq t_{0.05,7}$	$T \leq t_{0.05,7}$	$T \geq -t_{0.05,7}$	$T \geq -t_{0.05,7}$	$T \leq t_{0.05,7}$	$T \geq -t_{0.05,7}$
ANOVA results	Null hypothesis is accepted					

Table6: Correlation coefficient tests results

Correlations								
Pearson		method1	method3	method6	method7	method8	method10	Proposed
Proposed	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	8	8	8	8	8	8	8
**. Correlation is significant at the 0.01 level (2-tailed).								
Correlations								
Kendalstau_b		method1	method3	method6	method7	method8	method10	Proposed
Proposed	Correlation Coefficient	1.000**	1.000**	.982**	1.000**	1.000**	1.000**	1.000
	Sig. (2-tailed)	.	.	.001
	N	8	8	8	8	8	8	8

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A Genetic Algorithm Coupled with Tabu Search for Bi-Objective Permutation Flow Shop

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ABSTRACT

Considering flow shop scheduling problem with more objectives, will help to make it more practical. For this purpose, we have intended both the makespan and total due date cost simultaneously. Total due date cost is included the sum of earliness and tardiness cost. In order to solve this problem, a genetic algorithm is developed. In this GA algorithm, to further explore in solution space a Tabu Search algorithm is used. Also in selecting the new population, is used the concept of elitism to increase the chance of choosing the best sequence.

To evaluate the performance of this algorithm and performing the experiments, it is coded in VBA. Experiments results and comparison with GA is indicated the high potential of this algorithm in solving the multi-objective problems.

1. Introduction

The first research in flow shop scheduling problem has been done by Johnson [1]. Johnson described an exact algorithm for the minimization of makespan for flow shop scheduling problem with n jobs and 2 machines. Several algorithms such as branch and bound have been proposed to achieve the exact solution for this problem [2-5]. Thornton and Hunsucker [6] have proposed a new heuristic method for flow shop scheduling problems with the minimization of makespan with multiple processors and no intermediate storage. Bouquard et al. [7] has presented various forms of flow shop scheduling problem to minimize makespan. Recently many researchers have focused on the use of meta-heuristic algorithms to solve scheduling problems. (See [8-18]). Also, so many multi objective algorithms have been proposed. For example, Chang et al. [19] proposed two-phase subpopulation GA. In this approach simultaneously applies several subpopulations and assigns the weight for this subpopulation to explore the solution space uniformly. Hierarchical Fair Competition Model which divides the population into a hierarchical structure proposed by Hu et al. [20]. Mining Gene subpopulation GA that employs a mining gene technique based on the subpopulation genetic algorithm offered by Chang et al. [21]. Alves and Almeida [22] proposes a similar

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idea to the two-phase subpopulation genetic algorithm which proposed by Chang et al. [19]. Tan et al. [23] in their article are shown applying the immune algorithm to solve multi-objective problems. Two algorithms NSGA-II in Deb et al. [24] and SPEA-II in Zitzler et al. [25] are the best known algorithms for solving Multi-Objective scheduling problems. A multi-objective immune algorithm is proposed by Tavakkoli-Moghaddam et al. [26] for the flow shop problem and this algorithm is compared with a conventional multi-objective genetic algorithm, SPEA-II. Genetic algorithm integrated with artificial chromosomes for multi-objective flow shop scheduling problems is presented by Chang et al. [27]. In their article, an artificial chromosome generating mechanism is designed to reserve patterns of genes in elite chromosomes and to find possible better solutions.

In this paper, a flow shop scheduling problem is considered with two objectives. In order to solve this problem, a genetic algorithm is presented. In the proposed algorithm is used to elitism and tabu search algorithm to improve its performance. The following is a summary of the various parts of this article: In the next section we described the problem and its dimensions. The third section discusses the proposed algorithm and its features. In the fourth section, presents two examples and have examined the performance of the proposed algorithm. In the fifth section has been paid to conclusions of the paper.

2. Problem description

The flow shop scheduling problem (FSP) involves n jobs processed on m machines and if the sequences of processing jobs are the same for all machines, then the problem becomes permutation flow shop scheduling problem (PFSP). In this process, every job has some operations $O_{1,j}, O_{2,j}, \dots, O_{m,j}$ and each operation has a non-negative processing time t_{ij} . The job operation $O_{i,j}$ must be only executed on machine i . A machine cannot perform more than one operation per time. Operation $O_{i,j}$ can be performed only after operation $O_{i-1,j}$ [28].

In this paper we have considered two objectives makespan and total due date cost (ET_{\max}) as objective functions of our problem. Assume permutation job set is $\{\pi_1, \pi_2, \dots, \pi_n\}$, According to Yagmahan and Yenisey [29], completion times are shown as $C(\pi_i, j)$ then we have:

$$\begin{aligned}
 C(\pi_1, 1) &= t(\pi_1, 1) \\
 C(\pi_i, 1) &= C(\pi_{i-1}, 1) + t(\pi_i, 1) && i = 2, \dots, n \\
 C(\pi_1, j) &= C(\pi_1, j-1) + t(\pi_1, j) && j = 2, \dots, m \\
 C(\pi_i, j) &= \max\{C(\pi_{i-1}, j), C(\pi_i, j-1)\} + t(\pi_i, j) && i = 2, \dots, n ; j = 2, \dots, m
 \end{aligned}$$

Then,

$$f_1 = \text{Makespan} = C(\pi_n, m),$$

According to notation in Moslehi et al. [30], in a flow shop, earliness (E_i) and tardiness (T_i) of each job i , maximum earliness (E_{\max}), maximum tardiness (T_{\max}), and the sum of maximum earliness and tardiness are considered as total due date cost (ET_{\max}).

$$E_{\max} = \max_{\forall i} \{ \max \{ 0, d_i - t_{im} \} \} \quad i = 2, \dots, n$$

$$T_{\max} = \max_{\forall i} \{ \max \{ 0, t_{im} - d_i \} \} \quad i = 2, \dots, n$$

And,

$$ET_{\max} = E_{\max} + T_{\max},$$

Then,

$$f_2 = ET_{\max} = \text{Total Due date Cost} = \max_{\forall i} \{ \max \{ 0, d_i - t_{im} \} \} + \max_{\forall i} \{ \max \{ 0, t_{im} - d_i \} \}$$

$$i = 2, \dots, n$$

According to Shahsavari pour et al. [31], the fitness function is defined as Formula (1):

$$F_T = \left[w_{f_1} \times \frac{f_1 - f_{1_{\min}} + \gamma}{f_{1_{\max}} - f_{1_{\min}} + \gamma} \right] + \left[w_{f_2} \times \frac{f_2 - f_{2_{\min}} + \gamma}{f_{2_{\max}} - f_{2_{\min}} + \gamma} \right] \quad (1)$$

$$\text{And, } w_{f_1} + w_{f_2} = 1 \quad \text{and} \quad 0 \leq w_{f_1}, w_{f_2} \leq 1$$

where, w_{f_1} , w_{f_2} and are the planner-specified weight and indicate the relative importance of makespan and total due date cost. γ is a very small positive number in order to prevent dividing by zero in the fitness function. $f_{1_{\min}}$ and $f_{1_{\max}}$ are minimal and maximal values of makespan, $f_{2_{\min}}$ and $f_{2_{\max}}$ are minimal and maximal values of total due date cost in the current population.

3. Describing the presented GA

In this paper, a new genetic algorithm is proposed, which the following has been studied and explained the different features and parameters. First, to search deeper in each generation, some numbers of permutations are generated randomly and are added to total population for selecting in the next generation. By doing this procedure, are produced several new permutations in each generation. This increases the probability of finding an optimal answer for problem. In the second step, a tabu search algorithm (as described in the following) is generated, if they create better answers, the best of them is replaced by the first permutation. Thus, problem environment will checked more, and increases the probability of achieving the optimal solution. And finally, to avoid elimination of the top answers in every generation has used the concept of elitism. For this goal, in each generation some of the best sequences to be transferred directly to the roulette wheel in next generation. With this action with higher chance we will be able to keep the top answers in every generation.

Tabu search was introduced first by Glover [32] and then in the next articles paid to develop and introduce applications of this method [33-34]. This method is a sequential algorithm, that obtains a set of problem solutions, with successive moves from one solution x_n to another solution as x_{n+1} in its neighborhood $V(x_n)$. The movements are done with aim of reaching a good solution (optimal or near-optimal) and evaluate the objective function such $F(x)$ that must be minimized. A flow chart of algorithm is provided at Figure 1 and a pseudo code of this algorithm is shown below:

Pseudo-code for a simple tabu search (TS)

1. Set $n = 1$, Select x_0 and set $x^* = x_0$.
 2. Select x_i from $V(x_n)$.
 - 2.1- If the move $x_n \rightarrow x_i$ is on the tabu list set $x_{n+1} = x_n$ and go to 3
 - 2.2- If the move $x_n \rightarrow x_i$ is not on the tabu list set $x_{n+1} = x_i$,

Add the reverse move to the top of the tabu list

and delete the entry on the bottom.

If $F(x_i) < F(x^*)$, set $x^* = x_i$.
 3. Set $n = n + 1$.
Stop if stopping criteria are satisfied; otherwise go to 2.
-

4. Computational results

In this section, two examples are presented to evaluate the proposed method. To perform experiments we coded our algorithm in visual basic for applications (VBA) and run it in Intel T6570, 2.1 GHz with 2 GB RAM.

Example 1: At first is used from the paper Ho and Chang [35]. At this paper is presented an example with 4 machines and 5 jobs. The processing time of each job on each machine are given At Table 1. The objective is the minimization of makespan.

The best sequence obtained for this problem is (4, 2, 5, 1, 3) with the makespan = 213. We have implemented our algorithm 100 times with this processing time which the method presented in this paper has achieved to this number in 97% of the experiments. Table 2 shows the comparison of makespan value achieved by various articles.

Example 2: In this example we used the Reeves problems [36], which the test problems can be downloaded from OR-library web site (<http://people.brunel.ac.uk/~mastjjb/jeb/info.html>).

To find appropriate values for the parameters, algorithm was performed with different values, and the best values that obtained from the experiment are used as a basis for future experiments. Examples are including (20, 30, 50, 75) jobs and (5, 10, 15, 20) machines.

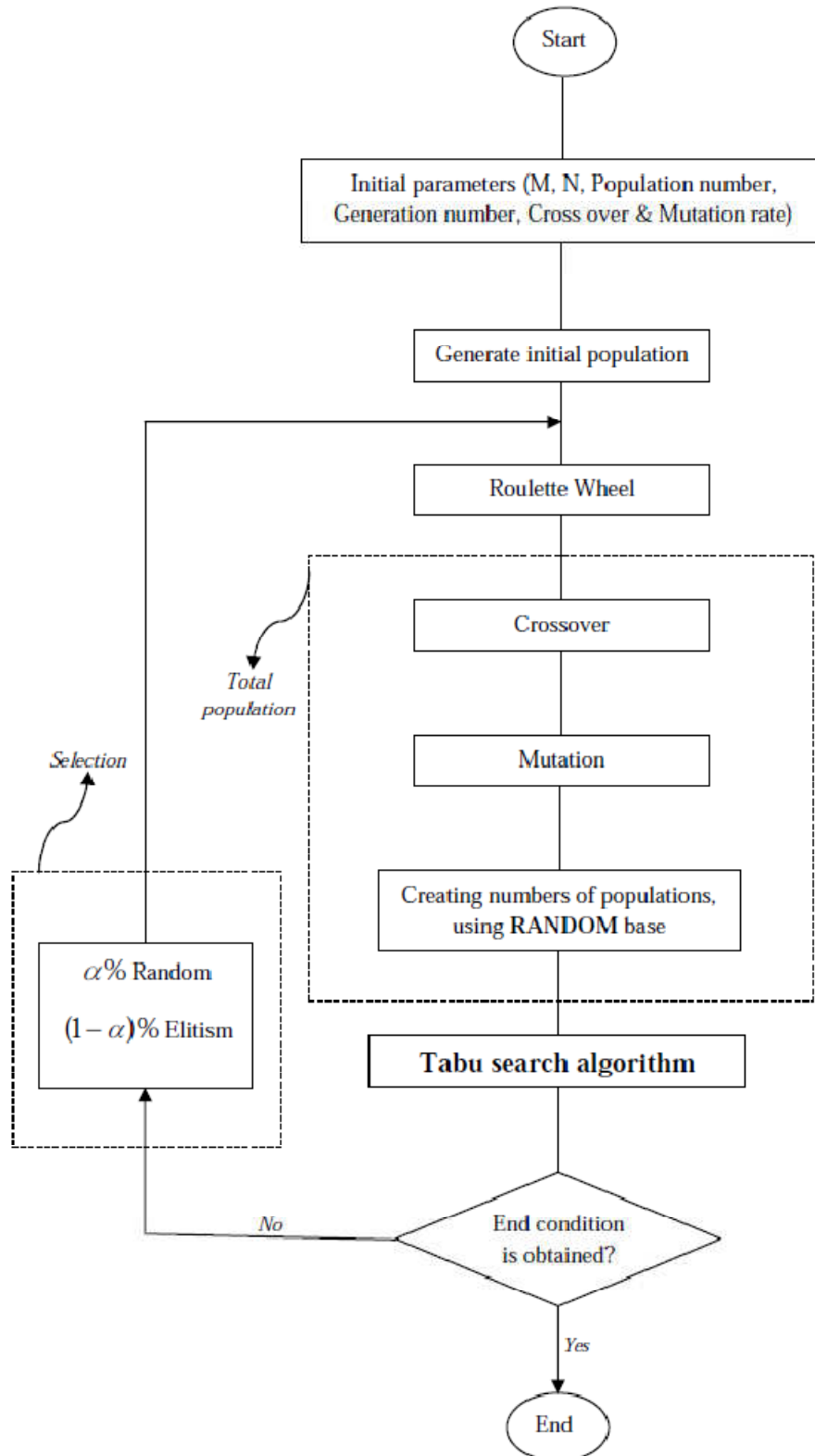


Figure 1. Flow chart of presented GA algorithm

The relative percentage increase (Δ) in any objective value for schedule T generated by any algorithm is given as (2). f_i' and f_i'' are objective value obtained by GA algorithm and

proposed algorithm which finds after run program 200 times for each problem. After finding the minimum for any objective, results are repeated 20 times to find $\Delta(f_1)$ and $\Delta(f_2)$, and their averages are selected as the output. The relative percentage increase in total objective value (Δ_t) for schedule T generated is calculated as formula (3). Equal relative weighting is chosen to the makespan and total due date cost for total objective value, then $\alpha_1 = \alpha_2 = 0.5$. The results are proposed in Tables 3. Results of experiments show the superiority of the proposed approach.

$$\Delta(f_i) = \left(\frac{f_i - \min(f'_i, f''_i)}{\min(f'_i, f''_i)} \right) * 100 \quad i = 1, 2 \quad (2)$$

$$\Delta_t = \alpha_1 \Delta(f_1) + \alpha_2 \Delta(f_2) \quad (3)$$

Table 1. Process times for the example

<i>Job</i>	M_1	M_2	M_3	M_4
J_1	31	41	25	30
J_2	19	55	3	34
J_3	23	42	27	6
J_4	13	22	14	13
J_5	33	5	57	19

Table 2. Comparison of different articles

Articles	Permutation	Makespan
Ho and Chang	(4, 2, 5, 1, 3)	213
Dannenbring	(5, 1, 2, 3, 4)	256
Gupta	(2, 1, 5, 3, 4)	251
Campbell et.al	(4, 2, 1, 5, 3)	246
Palmer	(5, 2, 4, 1, 3)	245
Hundal and Rajgopal	(4, 5, 2, 1, 3)	236
<i>NEW APPROACH</i>	(4, 2, 5, 1, 3)	213

Table 3. Result of comparison of GA with proposed algorithm

Problem number	$N \times M$	GA			Proposed approach		
		$\Delta(f_1)$	$\Delta(f_2)$	Δ_t	$\Delta(f_1)$	$\Delta(f_2)$	Δ_t
ReC01	20×5	0.79	1.73	1.26	0.37	0.29	0.33
ReC03	20×5	0.33	2.41	1.37	0.10	0.81	0.46
ReC05	20×5	0.91	1.09	1.00	0.49	0.20	0.35
ReC07	20×10	1.71	3.19	2.45	0.29	0.59	0.44
ReC09	20×10	0.70	1.61	1.16	0.92	0.18	0.55
ReC11	20×10	1.12	2.99	2.06	0.42	0.69	0.56
ReC13	20×15	1.01	0.99	1.00	0.18	1.91	1.05
ReC15	20×15	1.79	1.81	1.80	0.30	1.01	0.66
ReC17	20×15	1.42	2.78	2.10	0.68	0.92	0.80
ReC19	30×10	1.29	3.10	2.20	1.99	0.81	1.40
ReC21	30×10	1.82	2.61	2.22	0.38	0.30	0.34
ReC23	30×10	1.19	2.88	2.04	0.22	1.29	0.76
ReC25	30×15	1.92	1.30	1.61	0.81	1.04	0.93
ReC27	30×15	2.92	3.39	3.16	0.49	0.81	0.65
ReC29	30×15	1.28	1.29	1.29	1.39	1.30	1.35
ReC31	50×10	1.88	2.71	2.30	1.20	1.61	1.41
ReC33	50×10	2.18	1.06	1.62	1.16	0.72	0.94
ReC35	50×10	1.76	2.47	2.12	0.55	1.04	0.80
ReC37	75×20	2.77	1.17	1.97	0.82	0.69	0.76
ReC39	75×20	1.30	3.81	2.56	1.79	1.17	1.48
ReC41	75×20	1.81	2.91	2.36	1.20	0.92	1.06
Average		1.519	2.252	1.886	0.750	0.871	0.811

5. Conclusions

This paper presented an efficient algorithm for multi-objective problems. A bi-objective flow shop scheduling problem was considered to verify the performance of this algorithm. The makespan and total due date cost were this two objectives and Total due date cost was included the sum of earliness and tardiness cost. The genetic algorithms were presented for solving this problem involved some features that would help to improve its performance. In this algorithm, in order to improve local searching, the tabu search algorithm was used. The results of implementing these algorithms in the computer and comparison of them with genetic algorithm, showed better performance for presented algorithm. In future, this algorithm can be applied to other multi-objective problems.

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Customer Profitability Segmentation for SMEs Case Study: Network Equipment Company

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ABSTRACT

It is important to segment the most profitable customers of a company. Many CRM researchers have been performed to calculate customer profitability and develop a comprehensive model of it. This paper with the aid of data mining tools tries to customer segmentation based on kind of RFM. Customers are clustered using K-means and finally calculated CLV. This approach is essential for an SME to be able to provide a personalized service to each customer and to reach customer satisfaction.

1. Introduction

Customer relationship management (CRM) comprises a set of processes and enabling systems supporting a business strategy to build long term, profitable relationships with specific customers [1]. Customer data and information technology tools form the foundation upon which any successful CRM strategy is built. In addition, the rapid growth of the Internet and its associated technologies has greatly increased the opportunities for marketing and has transformed the way relationships between companies and their customers are managed [2, 3]. As corporations increasingly come to see customers as important assets, methods for estimating Customer Lifetime Value (CLV) have been developed as an important strategic marketing tool. CLV, which appears elsewhere in management literature as "customer equity" and "customer profitability" helps firms quantify customer relationships, illustrate the profitability of its customers and provides references for the allocation of marketing resources to customers and market segments [4]. In addition to long term customers buy more and less costly to serve whereas replacing existing customer by 'new' ones is known to be a more expensive [5]. Marketing managers can develop long-term and pleasant relationships with customers if they can detect and predict changes in their consuming habits [6]. Most previous studies are based on RFM model [7-10]. RFM incorporates three variable including Recency, Frequency, and Monetary to model customer's

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tendency of purchasing. Kind of RFM such as RF*M*, WRFM, LRFM, GRFM is expressed in different articles. Although these methods have been utilized in customer segmentation and behavior analyzing but preference of them are not apparent. In other word if our purpose is profitable customers clustering, It isn't clear which of models is suitable. This approach surveys all kind of RFM and compares techniques in case study for SMEs.

The rest of paper is organized as follows. Section 2 outlines the background and reviews CLV definition and RFM model and K-means technique. Section 3 describes the research methodology. Section 4 is implementation of study. Section 5 analyzes the result of customer segmentation and finally section 6 draws conclusions.

2. Literature Review

One important marketing concept in running today's business is the recognition of value of each individual customer. This concept is guiding today's business in developing personalized and value-added products and services. The value of a customer is defined as the profit resulting from payment of a transaction [11, 12]. Traditional customer segmentation models were based on demographic, attitudinal, and psychographic attributes of a customer .They gave too simple results and poor accuracy for today's complicated business environment. Recently, the customer segmentation based on customer transactional and behavioral data (e.g. purchases type, volume and history, call center complaints, claims, web activity data, etc.) collected by various information systems is commonly used. Customer profitability is a customer-level measure that refers to the revenues less the costs which one particular customer generates over a given period of time and has been studied the name of Customer value, customer valuation [13] , CLV, LTV, and Customer Equity [14]. RFM model is famous to CLV calculation.

2.1.RFM model

The RFM analytic model is proposed by Hughes. Recency (R) of the last purchase is the interval between the last purchase and a present time reference, so the lower recency is more valuable. Frequency (F) of the purchases is the number of transactions in a particular period, so the higher frequency is more valuable. Monetary (M) value of the purchases is the total amount of money paid by the customer over a particular period, so the higher monetary is more valuable. [9] Table1 is shown RFM definition and how it implemented.

In addition to traditional RFM, is presented method such as:

- WRFM: It dedicated weights to R, F, and M. For example, the highest weighting on the Frequency, followed by the Recency, with the lowest weighting on the monetary measure. To determine importance (weight) of RFM parameters, AHP method is exploited. [15]
- LRFM: It consists of four dimensions: relation length (L), recent transaction time (R), buying frequency (F), and monetary (M), to carry out customer clusters [16].

Table 1. RFM definition & implementation [11]

	Recency	Frequency	Monetary
Definition	The number of days between the last purchase and the time of analysis. The smaller the number, the higher the probability of next purchase	The number of purchases during a period of time. The higher the frequency, the higher the loyalty and value of a customer	Total amount of purchase during a period of time. The higher the amount, the higher the value of a customer Implementation
Implementation	Divide the sorted purchase dates into five equal intervals; then assign a weight 5 to the first 20%, 4 to the next 20%, and so forth	Divide the highest purchase count into five equal intervals; then assign a weight 5 to the first 20%, 4 to the next 20%, and so forth	Divide the total purchase amount into five equal intervals; then assign a weight 5 to the first 20%, 4 to the next 20%, and so forth

- GRFM: It emphasizes customers' purchasing behavior regarding different products. Chang and Tsai [17] propose new measure method takes into account the characteristics of the purchased items so that the calculated the RFM value for the customers are strongly related to their purchased items and can correctly reflect their actual consumption behavior.
- RF*M* : In cases such as Bank survey, because of numerous transactions , Bizhani and Tarokh [9] introduce new definition of R, F , M as fallow :
 $F^* = F / D$: number of transactions per day
 $M^*=M / F$: monetary unit value per transaction

According to previous studies, kind of RFM is shown in Table2.

As is mentioned, method of RFM had been used in several cases but each of them run one method. In this study, we perform all method to understand which method is suitable for case study.

2.2.K-means

Clustering is the process of grouping a set of physical or abstract items into classes of similar items where the groups are meaningful, useful, or both. A cluster is a collection of data items that are similar (or related) to one another within the same cluster and are dissimilar (or unrelated) to the objects in other clusters, so a cluster of data items can be treated collectively as one group and so may be considered as a form of data compression, which helps us easily annotate all the data items [9]. One of well- known data mining clustering technique is k-means [10]. The "K" in its name refers to the fact that the algorithm looks for a fixed number of clusters which are defined in terms of proximity of data points to each other the version described here was first published by J. B. MacQueen in 1967. For ease of explaining, the technique is illustrated using two-dimensional diagrams. Bear in mind that in practice the

algorithm is usually handling many more than two independent variables. This means that instead of points corresponding to two-element vectors (x_1, x_2), the points correspond to n -element vectors (x_1, x_2, \dots, x_n).

Table 2. Distribution of article according to RFM method

Technique	RFM Element	References	Case study
RFM	Recency	[18]	Retailer
	Frequency	[19]	-
	Monetary	[20]	-
		[21]	Service Company
		[22]	-
		[10]	Bank
		[23]	-
		[24]	Network Service
		[8]	Bank
		[25]	3G Mobile Company
RF*M*	R=Recency F*=Frequency /Day M*=M/F	[9]	Bank
GRFM	Group RFM (According to Purchase Item)	[17]	Amazon
LRFM	relation Length Recency Frequency Monetary	[16]	textile manufacturing
WRFM	Weithed RFM	[26]	hardware retail
		[27]	-
		[28]	-
		[29]	Car Manufacture
		[30]	Beauty Company
	[15]	Bank	

The procedure itself is unchanged [31]. One advantage of k-means clustering is that distance information for the items and clusters becomes readily available [32].

3. Methodology

3.1.Crisp methodology

There are different methodologies for implementing data mining projects but one of the powerful methods is CRISP (CRoss-Industry Standard Process for Data Mining) .As a process model ,CRISP provides an overview of the data mining life cycle. CRISP uses six phases to describe the process from gathering business requirements to deploying the: Business Understanding; Data understanding; Data preparation; Modeling; Evaluation; Deployment. [10]

3.2.Research methodology

According to CRIPS methodology the framework of article is shown in Figure 1.

4. Implementation

4.1.Business & data understanding

The case study of this article is about the SME Company that sells network equipment (such as switch, cable, modem, ...) . This company implemented CRM to use for registration of purchase information of customers. Purchase Data that is available in database, contains date, name and number of product , net price , discount and total price .for analyzing , we selected all purchases during one year (from 2010/03/21 to 2011/03/18). The Company has 351 customers and 1277 purchase records.

4.2.Data preparing

First of all, we should minus the refund of purchases from records to get accurate data for analyzing. For extracting R, F, and M parameters of each customer we aggregate records based on customer ID. In each aggregated record, there is a unique customer with her/his number of monetary transaction as F parameter, latest transaction date as R parameter and total amount of money in all of her/his deposit account at the end of the certain period (1 years) as M parameter. Then we scale each of these three parameters in five scales. For the scaling R parameter, first sort the data based on R attribute by ascendant order then partition the customers transaction dataset into 5 partitions.

Customers in the first partition have lowest value of Recency and their Recency value named 1, second partition named 2, third partition named 3, fourth named 4 and finally fifth partition named 5 . For the scaling F and M parameters the same procedure must be done. For LRFM, we need date that customer account is created on. Unlike Recency, if relation Length is older, it has more score. Table 3 is shown LRFM score.

4.3.Modeling & Evaluation

According to customer segmentation based on profitability, we must use clustering technique in this part. K-means is most popular in cases. To finding optimum k (count of cluster), we

need to calculate Dunn Index parameter. The main goal of this measure is to maximize intercluster distances (distance between different clusters), while minimizing intracluster distances (distance between members of a cluster). For any partition $C = \{C_1, C_2, \dots, C_k\}$, where C_i represents the i^{th} cluster of such partition, the Dunn indices, D , is defined as in equation (1):

$$D(C) = \frac{\min_{i,j=1,\dots,k, i \neq j} \delta(C_i, C_j)}{\max_{i=1,\dots,k} \Delta(C_i)} \quad (1)$$

where $\delta(C_i, C_j)$ defines the distance between clusters C_i, C_j (intercluster distance), and $\Delta(C_i)$ represents the intracluster distance of cluster C_i or the size of the cluster C_i , and k is the total number of clusters. In this study:

$$\delta(C_i, C_j) = d(\bar{C}_i, \bar{C}_j) \quad (2)$$

$$\Delta(C_i) = \max_{x \in C_i} \{d(x, \bar{C}_i)\} \quad (3)$$

where \bar{C}_i and \bar{C}_j are the centroid of cluster C_i and C_j . Thus large Value of D corresponds to good clusters. Therefore, the number of cluster that maximizes D is taken as the optimal number of clusters [15]. According to D in Chart 1, number of clusters (K) is 5 for customers in both RFM and LRFM clustering.

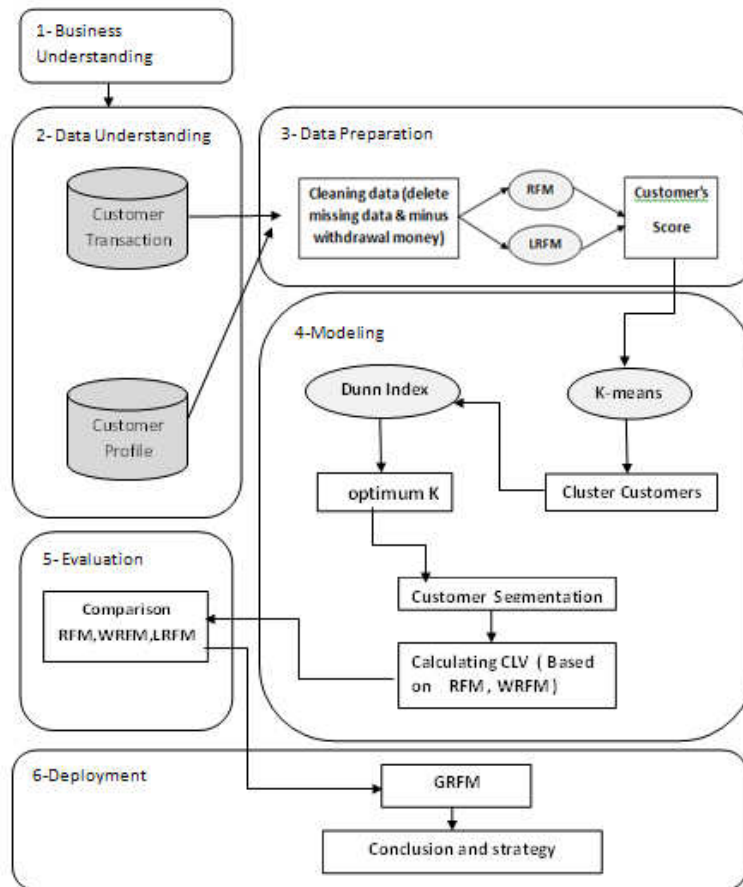
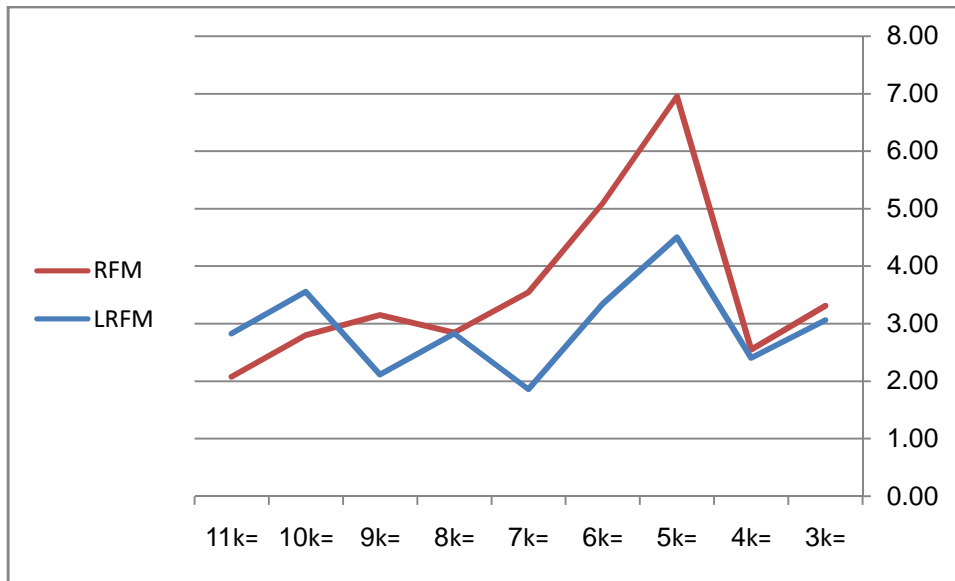


Figure 1. Research methodology

Table 3. Customer RFM score

Score	1	2	3	4	5
Relation Length	[1 :156]	[157 :301]	[302:554]	[555:625]	[626:663]
Recency	[256 :364]	[171 :256]	[98:170]	[39:97]	[1:38]
Frequency	[1:1]	[2:2]	[3:4]	[5:8]	[9:32]
Monetary	1 - 777500	777501 - 3051200	3051201 - 8174000	8174001 - 22880000	22880001 - 202559560

Chart 1. Dunn Index



We use the K-means method of SPSS to cluster the data .Table 4 is shown RFM clustering, Table 5 is shown LRFM clustering.

Table 4. RFM Cluster

Cluster	Number	R	F	M
c1	5	90	13	199985782
c2	268	159	2	4724449
c3	54	110	5	33955250
c4	7	78	9	166896814
c5	17	85	7	85301459

Table 5. LRFM Cluster

Cluster	Number	L	R	F	M
c1	4	222	52	10	192,134,025
c2	164	212	158	2	6,240,174
c3	142	624	147	2	8,932,326
c4	33	313	94	6	68,426,722
c5	8	626	98	11	174,958,814

The RFM score is calculated as follows,

$$\text{RFM Score} = \alpha * \text{Rscore} + \beta * \text{Fscore} + \gamma * \text{Mscore} \quad (4)$$

where α , β , γ are the weights of R,F,M respectively, and they mention the relative importance of the three variables. In traditional RFM and LRFM, we propose $\alpha=\beta=\gamma=1$ then calculate scores in Table 6, 7.

Table 6. LRFM Cluster

Cluster	L Score	R Score	F Score	M Score	LRFM
c1	2	4	5	5	16
c2	2	3	2	3	10
c3	4	3	2	4	13
c4	3	4	4	5	16
c5	5	3	5	5	18

Table 7. LRFM Cluster

Cluster	R Score	F Score	M Score	RFM
c1	4	5	5	14
c2	3	2	3	8
c3	3	4	5	12
c4	4	5	5	14
c5	4	4	5	13

After that, we calculate CLV that is similar to RFM score formula as follow:

$$CLV_{ci} = NR_{ci} \times \alpha + NF_{ci} \times \beta + NM_{ci} \times \gamma \quad (5)$$

where NR_{ci} refers to normal recency of cluster ci , NF_{ci} is normalized frequency, NM_{ci} is normalized monetary. In this study, min-max normalization method is used for normalizing data. Min-max normalization performs a linear transformation on the original data. Suppose that min_A and max_A are the minimum and maximum values of an attribute, A . Then min-max normalization maps a value, v , of A to v' in the range of $[newmin_A, newmax_A]$ by computing [30]:

$$v' = \frac{v - min_A}{max_A - min_A} (newmax_A - newmin_A) + newmin_A \quad (6)$$

So first, we normalize R, F, M of table 4,5 and calculate CLV. Because of setting $\alpha=\beta=\gamma=1$ for RFM scoring, also put 1 in weight in CLV formula. The result is shown in table5.

Table 8. CLV- RFM Based

Cluster	Normal R	Normal F	Normal M	CLV	Rank
c1	0.755494505	0.387096774	0.987293722	2.13	1
c2	0.565934066	0.032258065	0.023323752	0.62	3
c3	0.700549451	0.129032258	0.167630943	1.00	3
c4	0.788461538	0.258064516	0.823939458	1.87	2
c5	0.769230769	0.193548387	0.421117912	1.38	2

Table 9. CLV- LRFM Based

Cluster	Normal L	Normal R	Normal F	Normal M	CLV	Rank
c1	0.333837	0.85989	0.290323	0.948531	2.43	1
c2	0.318731	0.568681	0.032258	0.030807	0.95	3
c3	0.941088	0.598901	0.032258	0.044097	1.62	2
c4	0.471299	0.744505	0.16129	0.33781	1.71	2
c5	0.944109	0.733516	0.322581	0.86374	2.86	1

In WRFM, we do same work but according to the assessments obtained by the AHP method with regard to experts, the relative weights of the RFM variables are mentioned in table 10.

Table 10. Weights of RFM parameters

Parameter	R	F	M
Weight	0.105	0.258	0.637

Now we calculate CLV with these weights:

Table 11. CLV- WRFM Based

Cluster	$\alpha * R$	$\beta * F$	$\gamma * M$	CLV	Rank
c1	0.079327	0.099871	0.628906	0.81	1
c2	0.059423	0.008323	0.014857	0.08	3
c3	0.073558	0.03329	0.106781	0.21	3
c4	0.082788	0.066581	0.524849	0.67	1
c5	0.080769	0.049935	0.268252	0.40	2

4.4.Evaluation

Hitherto we present three methods for CLV calculation: RFM, WRFM, LRFM. The main goal of study is to find the best method to clustering profitable customers. By comparing the descriptive statistics quantity of RFM and LRFM clustering with the statistics for whole date set, in Chart 2 and 3, we find that when we have steady data, LRFM is better than RFM to **clustering** data. As is shown in charts, 76.4 % from whole of customer is clustered in one

group by RFM modeling but LRFM can divided data approximately in two cluster 46.72 % and 40.46 %.

Chart 2. NO Of Customer RFM

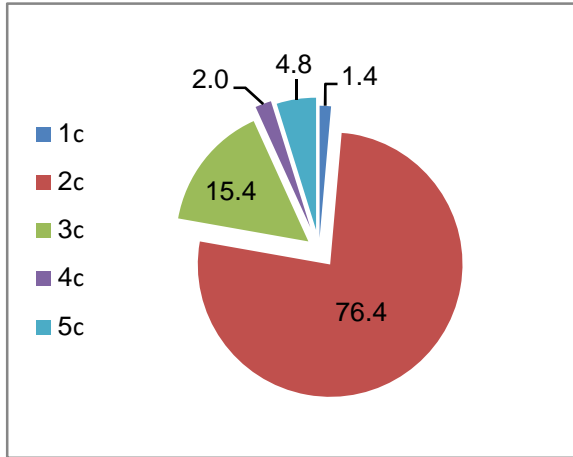
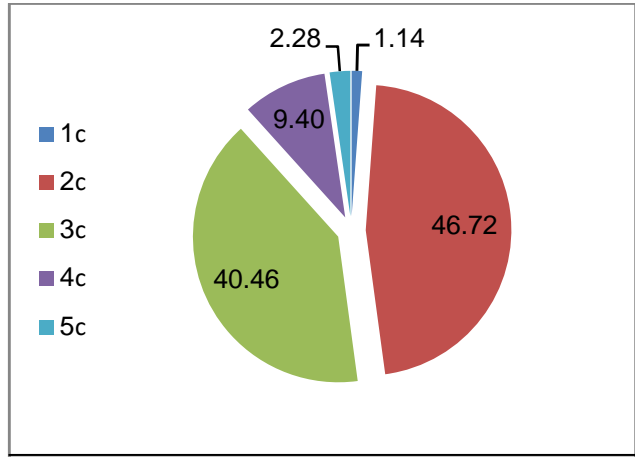
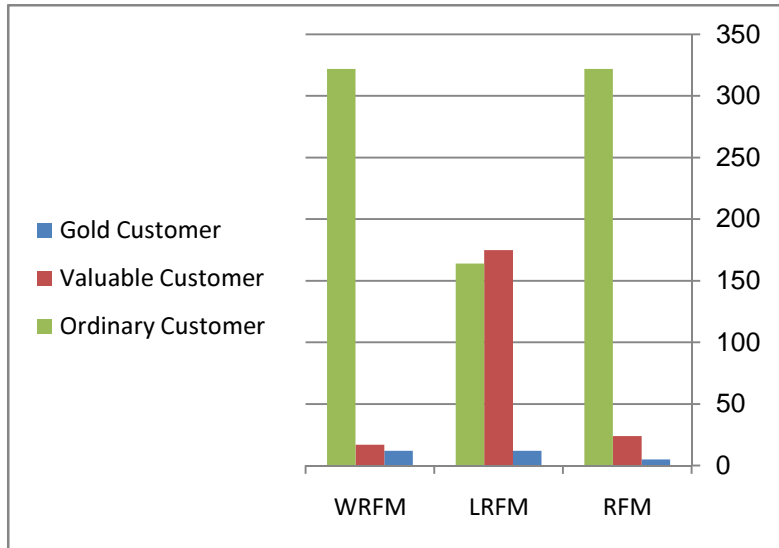


Chart 3. NO Of Customer LRFM



Also we segmented result of CLV in three methods to 1, 2, 3 ranking where 1 is Gold customer, Valuable Customer, Ordinary Customer in chart 4. Ranking in RFM and WRFM is similar, but LRFM is precision. According to different clustering, LRFM has better customer segmentation.

Chart 4 . CLV Ranking with RFM methods



Although we present the differences between RFM methods, it isn't enough to take decision about profitable customer group. We use GRFM to add products as a supplement in segmentation.

4.5. Deployment

Chang and Tsai [17] point out that RFM don't consider customers' purchasing behavior regarding different products while it is important because for example the frequency that a user buys a new notebook is very different from that of buying a new cloth. Moreover the amount of money spent on the above two items is very different. They propose the framework as follow steps: It first transforms each transaction record in the transaction dataset into an integer. It then creates an ORPA (ORiginal PATterns) table to store each integer and its occurrence frequency. The second phase follows to perform clustering over the ORPA table. Finally, the third phase calculates a (R, F, M) value for each customer in each cluster. Although this method really consider customers' purchasing behavior in RFM, but it isn't more suitable for profitable customer segmentation. In other word it is good to find customer consumption behavior since a customer may belong to more than one cluster, a customer may be associated with different (R, F, M) values but our study focuses in finding profitable customers segmentation which only each customer can belong to one segment. So we consider product purchase items in new three steps:

- In according to product purchase records, find top ten products that have most price toward all purchases (Table 12)
- Consider which customer purchases these products from Gold customer in RFM, WRFM, and GRFM.
- Finally each customer has belonged to one of three groups and purchase at least one product is shown in table 12, is profitable customer (Table13). It means:

$$\text{Gold Customers} = \cup(\text{Gold Customer}_i \cap \text{Purchase Product}_i)$$

$$\text{where } i = \text{RFM, WRFM, LRFM (7)}$$

First we find Top 10 product based on total price of all products that is shown in table 12.

Table 12. Top 10 products

Product	Unit Price	Price	Percentage
A	7,951,160	405,509,159	2.53
B	5,728,142	463,979,486	2.90
C	1,352,911	465,401,405	2.91
D	3,388,880	474,443,219	2.96
E	507,760	480,341,428	3.00
F	2,350,519	498,310,000	3.11
G	2,536,110	507,222,000	3.17
H	3,401,513	517,030,000	3.23
I	4,654,034	544,522,000	3.40
J	625,296	622,169,739	3.89

Table 13. Top 10 products

Customer ID	A	B	C	D	E	F	G	H	I	J
192										
285										
349										
30										
252										
174										
139										
34										
247										
43										
105										
170										
200										

In order for comparison, according to customers of Gold segmentation in Chart4 and their purchase, is filled table 13 that is shown union of three group of customers that purchase top10 product. So between 351 customers only 13 customers are profitable that 30% income of company is result of their purchases. In addition to finding profitable customer by GRFM, it is specifies which products is purchased to each other such as C and E usually is bought together.

5. Discussion and Conclusion

One of the key purposes of marketing is to identify the target profitable customers and analyze it. Information is essential for an SME to be able to provide a personalized service to each customer and to make the customer feel valued by business. It is important that only implementation of CRM in SME isn't enough, It is essential to use data mining tools for analyzing customer purchase behavior to run strategies such as price discrimination, that lead to service improvement and customer satisfaction.

In this paper, we presented the compilation RFM that integrated RFM, WRFM, LRFM and consider customers' purchasing behavior regarding products. As case study, we used SMEs that sells network equipments. This company has 351 customers and 1277 purchase records during one year (from 2010/03/21 to 2011/03/18). At first we modeled purchase date with kind of RFM techniques and clustered customers by using k_means. Then was calculated CLV and compared results . In our case RFM and WRFM had similar outcome. For clustering LRFM was better toward another because the frequency of most customers was 1

and 2, LRFM can divided them according relation length. Although customers were segmented in Gold, Valuable and Ordinary groups but we used top 10 products (according to whole of purchase price) to revised gold customer in 3 methods and union of them. Finally we found 13 customers as gold customer.

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A Hybridized Lagrangian Genetic Algorithm for Designing an Integrated Supply Chain Network: A Case Study Approach

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ABSTRACT

This paper investigates the problem of designing an integrated production-distribution system which supports strategic and tactical decision levels in supply chain management. This overall optimization is achieved using mathematical programming for modeling the supply chain functions such as location, production, and distribution functions. Our model intends to minimize the total cost including production, location, transportation, and inventory holding costs. In view of the NP-hard nature of the problem, this paper provides a hybrid algorithm incorporates Genetic Algorithm into Lagrangian Relaxation method (namely HLRGA) to update the lagrangian multipliers and improve the performance of LR method. The effectiveness of HLRGA has been investigated by comparing its results with those obtained by CPLEX, hybrid genetic algorithm, and simulated annealing on a set of supply chain network problems with different sizes. Finally, an industrial case demonstrates the feasibility of applying the proposed model and algorithm to the real-world problem in a supply chain network.

1. Introduction

Supply chain management (SCM) is the systematic analysis and educated decision-making within the different business functions of an organization resulting in smooth and cost-effective flows of resources – material, information, and money. In other words, it is the coordination and synchronization of the flow of resources in the network of suppliers, manufacturing facilities, distribution centers (DCs) and customers. These network elements form the different echelons of the supply chain [1]. Decisions are made across the supply chain on three levels: strategic, tactical and operational. Strategic decisions are long term decisions where the time horizon may be anything from one year to several years i.e. it involves multiple planning horizons. Tactical decisions are taken over a shorter period of time, maybe a few months. These are more localized decisions taken to keep the organization on the track set at the strategic level. Operational decisions are similar to day-to-day decisions for planning a few days worth of operations. These take into consideration the most profitable way to carry out daily activities for satisfying immediate requirements.

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The strategic configuration of the supply chain is thus a key factor influencing the efficiency at tactical and operational level. Its long term impact on the efficiency of the supply chain, combined with the commitment of substantial capital resources, render this level crucial. One of the most important aspects of strategic level is location problem that leads the system to define the optimal number of facilities, location of facility in geographical manner, assigning the customers to facility and configuration of transportation network. Melo et al. [2] presented a comprehensive review based on SC features. According to [2], approximately 82% of literature deals with single period problems. Likewise, there is a gap in 3-layers, Multi periods and Multi products integrated SC and facility location models, as they have suggested researching in this case. So, in this paper, a 3-layers SC model includes location-allocation problem is presented. Also, the proposed model is extended in multi periods and multi products.

There is a vast amount of literature available on supply chain management research dealing with the different aspects of the subject. Numerous models in the literature, conceptual as well as quantitative, refer to the planning and quantitative aspects of the different business functions: location, production, inventory and transportation. A number of quantitative models use mixed-integer programming (MIP) to solve the supply chain optimization problems. One of the first attempts was done by Geoffrion and Graves [1], where a MIP model was formulated for the multiple commodity location problem. This seminal research involved the determination of distribution center (DC) locations, their capacities, customer zones and transportation flow patterns for all commodities. A solution to the location portion of the problem was presented, based on Bender's Decomposition (BD).

Cohen and Lee [3] develop an analytical model to establish materials requirements policy based on stochastic demand. They develop four different sub-models with a minimum-cost objective. A mathematical algorithm at the end decides the optimal ordering policies to minimize the costs. A MIP model for a production, transportation, and distribution problem has been developed by Pirkul and Jayaraman [4] to represent a multi-product tri-echelon capacitated plant and warehouse location problem. The model minimizes the sum of fixed costs of operating the plants and warehouses, and the variable costs of transporting multiple products from the plants to the warehouses and finally to the customers.

Schmidt and Wilhelm [5] present a review of the work done on different decisional levels in the supply chain with respect to time frames – strategic, tactical and operational. Modeling issues are discussed at each level and a prototype formulation is provided as an extension of the discussion. Cordeau et al. [6] propose a static model considering a multi-commodity, multi-facility and single-country network. The decision variables concern the number of locations, the capacity and technology of manufacturing in plants and warehouses, selection of suppliers, selection of distribution channels, transportation modes and material flows.

Vila et al. [7] propose a dynamic model in a much more specialized context. They consider an application in the lumber industry, but their model can be applied to other sectors. The authors consider an international network, with deterministic demands. They consider external suppliers, capacitated plants and warehouses, the choice between a set of available technologies, the possibility of adding capacity options to the facilities, and a list of substitute

products to replace standard ones. Other studies which address the SC coordination issues at different decision levels have been developed [8-12]. These conventional methods generally consider an overall production strategy, inventory strategy and flow of products through a facility over a single period to minimize total costs or maximize profits [13].

Supply chains have been more or less integrated to some extent as a whole, or in parts. Integration, if done at all, has been mostly done in patches throughout the supply chain. In many cases, this has been driven more by the need to survive and improvise, than by the willingness to improve and advance further. Therefore, efforts must be made to integrate suppliers, manufacturers, distributors, and customers, so that they will collaborate effectively with each other in the entire network. During the past few years, there have been significant attempts for providing integrated supply chain problems, which includes suppliers, manufacturers, distributors and retailers. The primary objective of an integrated supply chain is to optimize all cost components from converting raw materials into final products delivered to end users [14-16].

The decisions made for network design determines the suppliers, manufacturing plants, and intermediate inventory warehouses, selects the distribution channel from suppliers to customers, and identifies the transportation volume among distributed facilities for multiple period horizon. From operational perspective, it is critical to have a coordinated plan for production and distribution activities of multiple level production factories and distribution centers in order to take full advantage of the supply network [17, 18]. In general, production and distribution planning involve raw material suppliers, manufacturing plants, intermediate warehouses, distribution centers and customers which are interconnected in terms of the interconnected in terms of supplier/customer relations.

The objective of this paper is to simultaneously optimize the decision variables of different functions that have been traditionally optimized sequentially [9]. Hence in this study, we will develop an integrated strategic and tactical supply chain model in a multi-echelon, multi-level, multi-period supply chain network. The problem, therefore, is modeled as a mixed integer linear programming formulation that seeks to optimize fixed charge DCs costs, fixed and variable production costs, transportation costs between plant to DCs and DCs to customer zones, inventory holding costs and backorder costs while satisfying all customer demands, plant and DCs capacity. After formulating the problem

The main contributions of my project can be summarized as follows:

- Introducing a novel integrated strategic and tactical SC planning model by integrating location and production-distribution planning activities into a multi-echelon, multi-level and multi-period SC network.
- Developing a hybrid algorithm which combined the lagrangian relaxation method and genetic algorithm to solve the candidate problem.
- Applying the model and algorithm to a real industrial case for implementing the feasibility of applying the proposed model to a real-world problem.

This paper is organized as follows: the mathematical model of the SCN design problem is given in section two. While third section includes an explanation about the proposed HLRGA, the brief description of the hybrid genetic algorithm and simulated annealing

algorithms used in computational experiments are given in section four. Moreover, the fifth section gives computational results and presents an industrial case. This is followed by conclusions in the sixth section.

2. Mathematical Model

In this research we consider a multi-plant, and multi-customer location-production-distribution system. The system contains a set of manufacturing facilities with limited production capacities situated within a geographical area. Each of these facilities can produce one or all of the products in the company's portfolio. The customer demands for product are to be satisfied from this set of manufacturing facilities. There are fixed costs associated with each facility location which may include land costs, construction and fabrication costs etc. Although we assume that the customer allocation has to be done within the existing set of manufacturing facilities, sometimes it may be necessary to make changes or expansions in the current facilities to accommodate the production quantities which ultimately will prove to be beneficial. Costs for these changes would be included in the fixed costs. So the production capacities of each of these facilities effectively represent its current and potential capacities. When the number of customers is large and the distances between them and the deot, or sources are long it is often beneficial to utilize distribution centers. This makes the model much more complicated as products can now be shipped straght from the sourcee to customer, or products may be shipped to the customer via a distribution center, as shown in Figure 1.

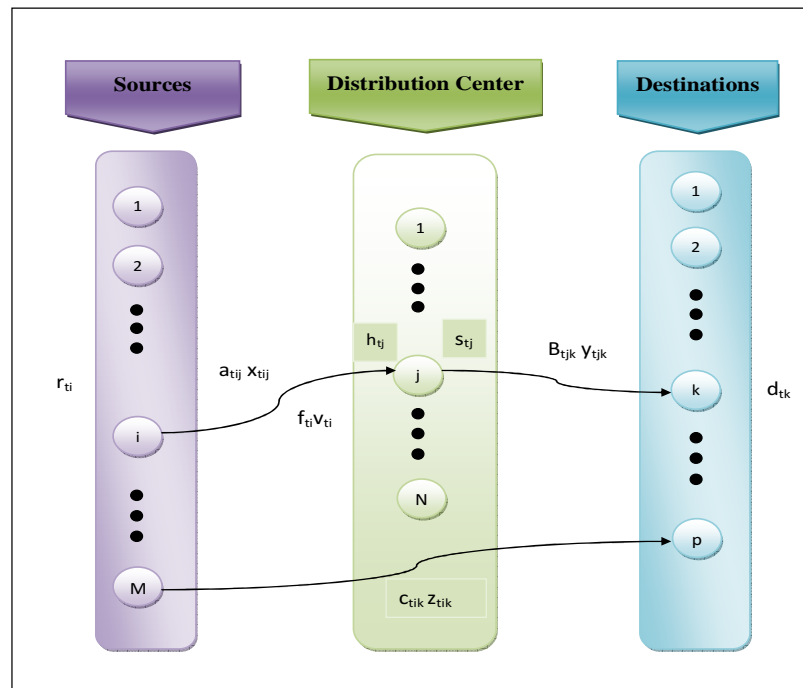


Figure 1. A real-world supply chain network

The addition of the distribution centers makes the system much more flexible. For example, transshipments can now occur at the distributions centers: product may be shipped from

multiple sources to the distribution centers and then shipped from there to a single customer. It also allows for the possibility of inventory to be held at the distribution centers. Thus, inventory can be shipped to a distribution center during one time period and held there for delivery during another time period. To optimize this model, however, both fixed and variable costs now need to be taken into account. Variable costs include the costs of transporting products between the sources, the distribution centers, and the final customers, as well as the cost of holding inventory at the distribution centers.

Below is a proposed mathematical model to represent the distribution and inventory problem with set-up costs. This model takes into account possible inventory at the distribution centers, set-up costs associated with operating each source, and time periods. This model works on the assumption that all demands are met in the time period they occur, and that the starting and ending inventories at all distributions centers are zero. The following notations are used to define the mathematical model:

Parameters:

- M = Number of sources (plants)
 N = Number of distribution centers
 H = Number of time periods in the planning horizon
 P = Number of customers
 BM = A big number
 a_{ij} = Unitary transportation cost from source i to distribution center j
 PC_{it} = Variable cost to produce a unit of product in source i during time period t
 h_{ij} = Inventory cost in distribution center j at the end of period t
 b_{ijk} = Unitary transportation cost from distribution center j to customer k during time period t
 c_{ik} = Unitary cost of transportation units directly from source i to customer k during time period t
 r_{it} = Products available in source i during time period t
 d_{tk} = Demand at customer k during time period t
 f_{ii} = Setup cost associated with transportation products from source i

Variables:

- x_{ij} = Number of products to be sent from source i to distribution center j during time period t
 q_{it} = Quantity of products produced in source i during period t
 s_{ij} = Inventory at distribution center j at the end of time period t
 y_{ijk} = Number of products to be sent from distribution center j to customer k during time period t
 z_{ik} = Number of products to be sent directly from source i to customer k during time period t
 u_j = 1 if distribution center j is opened, 0 otherwise
 v_{ii} = 1 if $x_{ij} > 0$, 0 otherwise

Mathematical model:

The production-distribution problem can be formulated as follows:

$$\begin{aligned} \text{Min } Z = & \sum_{t=1}^H \sum_{i=1}^M \left(\sum_{j=1}^N a_{tij} x_{tij} + \sum_{k=1}^P c_{tik} z_{tik} + f_{ti} v_{ti} \right) \\ & + \sum_{t=1}^H \sum_{j=1}^N \left(\sum_{i=1}^M b_{tij} y_{tij} + h_{tj} s_{tj} \right) + \sum_{t=1}^H \sum_{i=1}^M PC_{it} q_{it} \end{aligned} \quad (1)$$

Subject to

$$\sum_{j=1}^N x_{tij} + \sum_{k=1}^P z_{tik} \leq r_{ti} \quad \forall t, i \quad (2)$$

$$\sum_{j=1}^N y_{tjk} + \sum_{i=1}^M z_{tik} = d_{tk} \quad \forall t, k \quad (3)$$

$$\sum_{j=1}^N x_{tij} \leq q_{it} \quad \forall t, i \quad (4)$$

$$\sum_{j=1}^N z_{tij} \leq q_{it} \quad \forall t, i \quad (5)$$

$$\sum_{i=1}^M x_{tij} + s_{t-i,j} - s_{t,j} - \sum_{k=1}^P y_{tjk} = 0 \quad \forall t, j \quad (6)$$

$$\left(\sum_{j=1}^N x_{tij} + \sum_{k=1}^P z_{tik} \right) - Bv_{ti} \leq 0 \quad \forall t, j \quad (7)$$

$$x_{tij} \leq BMu_j \quad \forall t, i, j \quad (8)$$

$$y_{tjk} \leq BMu_j \quad \forall t, i, j \quad (9)$$

$$s_{0,j} = s_{Q,j} = 0 \quad \forall j \quad (10)$$

$$x_{tij} \geq 0, y_{tjk} \geq 0, z_{tik} \geq 0, s_{tj} \geq 0 \quad \forall t, i, j, k \quad (11)$$

In this model, namely PRDIS model, the goal of objective function (1) is to minimize the producing, shipping, inventory, and set up costs. The summations in the objective function represent these costs. The first set of summations represents the cost of shipping from the source to the distribution centers, the cost of shipping from a source straight to a customer, and the setup of cost of operating from those sources. The set-up cost is included with the use of the binary variable v_{ti} . The second set of summation represents the cost of shipping from the distribution centers to the customers, and the cost of holding any inventory at the distribution centers.

The next set of equations represents the constraints of the model. The first set of constraints (2) ensures the total amount shipped from each source (total to all distribution centers and to all customers) is less than that source's capacity in each time period. The second set of constraints (3) ensures the demands at each customer are met during each time period. Constraints (4) ensure that the total number of products delivered from the source i to distribution center j during time period t is equal to production number in a given period t . Constraints (4) ensure that the number of products to be sent directly from source i to

customer k during time period t is equal to production number in a given period. The next set of constraints (6) is a conservation constraint. This set of constraints ensures that the products at the beginning of the time period plus the products entering the distribution center minus the products shipped from the distribution center is equal to the products counted as on-hand inventory at the start of the next time period. The next set of constraints (7) ensures that the set-ups costs are considered. If any products are shipped from a source (either to a distribution center or to a customer) during a time period, then the value of the binary variable v_i will be 1, and the set-up costs for that time period will be included in the objective function. If no products are shipped, then this value is 0, and the set-up costs for that source and time period are disregarded. Constraints (8) and (9) guarantee the assignment of customers and transportation to open DCs. The next set of constraints (10) ensures that the inventory at the beginning and end of the planning horizon at each distribution center is zero. Finally, the last set of constraints (11) ensures that non-negativity and binary conditions hold

3. Proposed Hybrid Algorithm

Supply chain network design is to provide an optimal platform for efficient and effective SCM. This is an important and strategic operations management problem in SCM. The design task involves the choice of facilities (plants and distribution centers (DCs)) to be opened and the distribution network design to satisfy the customer demand with minimum cost. It belongs to a production-distribution and facility location-allocation problem. Solution approaches for these problems are optimization algorithms within the framework of Benders' decomposition [1, 19], heuristics based on branch-and-bound [20], and Lagrangian relaxation [21]. However, these techniques consume extensive amounts of time and effort in finding optimal solutions for realistically sized problems. The problem under consideration can be reduced to the well-known p -median problem which is known to be NP-hard [22]. Therefore, researchers have utilized heuristic and meta-heuristic approaches to solve this problem.

Syarif et al. [23] have developed a spanning tree-based GA approach for the multi-source, single-product, multi-stage SCN design problem. Jayaraman and Ross [24] have also proposed a heuristic approach based on simulated annealing for the designing of distribution network and management in supply chain environment. Yeh [25] has proposed a memetic algorithm (MA) which is a combination of GA, greedy heuristic, and local search methods for the same problem. The author has extensively investigated the performance of the MA on the randomly generated problems.

Due to the limitations involved in exhaustive enumeration, branch and bound and mathematical modeling for solving large sized problems, researchers started developing heuristics. Even though these heuristics did not guarantee optimal solutions, they gave feasible solutions within a reasonable computational time [26]. A heuristic method is a procedure that is likely to find a good feasible solution but leaves no guarantee of its quality or whether it is optimal or not [27]. All the possible solutions are not considered, since that would require an infinite amount of time, but rather a part of the solution space with solutions that might or might not be optimal. The solution space is searched smarter, discarding those parts that certainly not will contain good solutions and focusing more on those parts that

could include a good one. Nevertheless, a well-designed heuristic method can often provide a near-optimal solution, or indicate that no optimal solution exists. The method should also be efficient enough, so that it can deal with large problems within a reasonable time.

The problem with ordinary heuristic methods is that for every problem given, a procedure must be designed to fit and to solve the problem [27, 28]. However, in recent years another type of procedure has been developed, the meta-heuristic that consists of both a general structure and strategy guidelines to adjust to the specific problem given. This approach is very timesaving and meta-heuristics have become an important tool for solving a wide range of practical problems. Furthermore, ordinary heuristics often are local improvement procedures, i.e. they try to improve the current solution within the local neighborhood of that solution. This means that for every iteration, the method will find a solution near the current one and accept it if it's better, converging towards the local optimum within the neighborhood of the starting solution. The drawback of this approach is that if the given problem consists of multiple local optima, the procedure applied will converge to one local optimum and then stop.

The algorithm developed to solve the integrated production-distribution with set-up costs uses a combination of genetic algorithm and Lagrangian relaxation techniques. First, an algorithm using the method of GA is developed to solve an uncapacitated PRDIS model. Next, a relaxed model of PRDIS is developed using the method of Lagrangian relaxation. Finally, the GA algorithm is used in conjunction with subgradient optimization to solve the Lagrangian relaxation model, and produce a solution to the PRDIS model itself.

3.1. Proposed Genetic Algorithm

For larger and more complicated problems, meta-heuristic procedures are used, where the search method combines local improvement procedures with more advanced and intelligent strategies to create a process capable of escaping from local optima and performing a robust search of the solution space. An important characteristic of the meta-heuristic is hence the possibility to escape from a local optimum after reaching it, and depending on the method, there are different ways of doing so. One common way, besides searching locally for better solutions than the current one, is to also have the possibility to accept a neighbor solution if it is worse than the current one. Another way is to prohibit solutions, within the current solution neighborhood, to force the procedure to search in another direction away from a local optimum.

In this section, representation and genetic operators which were used in GA for multi-objective design of SCN will be explained.

3.1.1. Representation

The representation scheme for the decision variables is a key point before using GAs to solve an optimization problem. This representation decides how the problem will be shown in the GA. There are three ways of encoding tree: (1) edge-based encoding, (2) vertex-based encoding and (3) edge-and-vertex encoding [29].

In this study, to escape from these repair mechanisms in the search process of GA, we used priority based encoding developed by Gen and Cheng [29]. They had successfully applied this encoding to the shortest path problem and the project scheduling problem. The first application of this encoding structure to a single product transportation problem was carried out by [30]. In priority- based encoding, the position of a gene is used to represent a node (source in transportation network), and the value is used to represent the priority of corresponding node for constructing a tree among candidates.

3.1.2. Evaluation

The purpose of the evaluation function is to measure the fitness of candidate solutions in the population with respect to the objective functions and constraints of the model. The fitness values are used to select parent solutions to create the next generation of solutions. The fitness of an individual dictates the number of copies of that solution in the mating pool. In this paper, the evaluation is achieved by the sum of the objective function (Eq. (1)) and the penalty terms of constraint violation.

3.1.3. Crossover

The crossover operators produce offspring by exchanging information contained in the parents. The proposed GA uses a simple crossover operator in which a random crossover point is determined along the length of the chromosome and swamps the right hand side segments of the parents. The crossover operation is done with a probability called the crossover probability. A segment-based crossover operator which was based on uniform crossover is used in this paper. In this operator, each segment of offspring is randomly selected with equal chance among the corresponding segments of parents. As it is seen in Figure 2, crossover operator utilizes from a binary mask. Its length is equal to number of stage in SCN. While “0” means that the first parent will transfer its genetic materials to the offspring, “1” means that the offspring will take genetic materials from the second parent for the corresponding segment. This crossover operator tends to preserve good gene segments of both parents.

	1	2	3	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5
Parent 1	3	7	4	2	6	5	1	4	5	6	8	3	2	7	1	1	1	3	3	3
Parent 2	1	4	5	6	7	3	2	8	1	3	5	7	6	4	2	1	3	2	2	3
Binary Mask	0							1							0					
Child	3	7	4	2	6	5	1	8	1	3	5	7	6	4	1	1	1	3	3	3

Figure 2. An illustration of crossover operator

3.1.4. Mutation

The mutation operator acts on a single chromosome to alter the information contained in the genes. In this operator, firstly, a decision about which segments will be mutated is given with probability of 0.5 (i.e. using a binary mask), and then selected segments are mutated. Swap operator is used for chromosome. The scheme of mutation operator is shown in Figure 3.

Parent	1	2	3	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5
	3	7	4	2	6	5	1	8	1	2	5	7	6	4	1	1	1	3	3	3
Binary Mask	1							0												1
Child	1	2	3	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5
	3	2	4	7	6	5	1	8	1	2	5	7	6	4	1	1	2	3	3	3

Figure 3. An illustration of mutation operator

3.1.5. Selection strategy

After obtaining the fitness value of each chromosome, chromosomes will then be selected. This is the vital process in the algorithm since it selects the parents to produce offspring and optimal solution will be obtained among the new solutions. Chromosomes with higher fitness value will have a higher chance of being selected more often. This is achieved by assigning a probability value to each chromosome selected, so that better chromosomes will be assigned a higher probability. The roulette wheel selection strategy is used in this research.

3.2. Hybrid Lagrangian Genetic Algorithm

One method frequently used to solve linear programming problems is that of Lagrangian relaxation. The general approach of Lagrangian relaxation can be found in [31, 32]. This method can also be applied to the DIPS model. Using the same parameter and variable definitions as the proposed model, the relaxed model is:

$$\begin{aligned}
 \text{Min } Z = & \sum_{t=1}^Q \sum_{i=1}^M \left(\sum_{j=1}^N a_{tij} x_{tij} + \sum_{k=1}^P c_{tik} z_{tik} + f_{ti} v_{ti} \right) \\
 & + \sum_{t=1}^Q \sum_{j=1}^N \left(\sum_{i=1}^M b_{tij} y_{tij} + h_{tj} s_{tj} \right) + \sum_{t=1}^Q \sum_{i=1}^M PC_{it} q_{it} \\
 & + \sum_{t=1}^Q \sum_{i=1}^M \lambda_{ti} \left(\sum_{j=1}^N x_{tij} + \sum_{k=1}^P z_{tik} - r_{ti} \right)
 \end{aligned} \tag{12}$$

Subject to

$$\sum_{j=1}^N y_{tjk} + \sum_{i=1}^M z_{tik} = d_{tk} \quad \forall t, k \tag{13}$$

$$\sum_{j=1}^N x_{tij} \leq q_{it} \quad \forall t, i \tag{14}$$

$$\sum_{j=1}^N z_{tij} \leq q_{it} \quad \forall t, i \quad (15)$$

$$\sum_{i=1}^M x_{tij} + s_{t-i,j} - s_{t,j} - \sum_{k=1}^P y_{tjk} = 0 \quad \forall t, j \quad (16)$$

$$\left(\sum_{j=1}^N x_{tij} + \sum_{k=1}^P z_{tik} \right) - Bv_{ti} \leq 0 \quad \forall t, j \quad (17)$$

$$x_{tij} \leq BMu_j \quad \forall t, i, j \quad (18)$$

$$y_{tij} \leq BMu_j \quad \forall t, i, j \quad (19)$$

$$s_{0,j} = s_{Q,j} = 0 \quad \forall j \quad (20)$$

$$x_{tij} \geq 0, y_{tjk} \geq 0, z_{tik} \geq 0, s_{tj} \geq 0, \lambda_{ti} \geq 0 \quad \forall t, i, j, k \quad (21)$$

In this model, the objective function is updated to reflect the lagrangian multipliers and the first constraint from the first model as a penalty function. The remaining constraints ((13)-(21)) now directly mirror the constraints of the uncapacitated model ((3)-(11)).

For the resulting model it will be necessary to find an efficient scheme to update the Lagrangian multipliers λ_{ti} . The general approach to this updating is the *Subgradient Optimization* technique as described in [32, 33]. In the subgradient optimization method, the lagrangian multipliers, λ_{ti} , are updates using the gradient of the solution with respect to λ . Thus, the entire model can be solved by combining the methods of genetic algorithm with subgradient optimization. In this algorithm, the relaxed model is solved using the method of genetic algorithm as presented in section 3.1 by updating the objective function of the uncapacitated production-distribution model with the objective function of the Lagrangian relaxed model. This solution is then used to update the lagrangian multipliers by the method of subgradient optimization. This process is repeated until a stopping criteria is reached (either the lagrangian multipliers converge or a set number of iterations is performed). This method is outlined below in Figure 4.

The program first initializes the lagrangian multipliers, passes them to the Genetic Algorithm to update the uncapacitated production-distribution model objective function, solve the model, and projects the solution back to the feasible region. The program then passes that solution and the lagrangian multipliers to the subgradient optimization algorithm to update the lagrangian multipliers and evaluates the improvement of the solution, and repeats this process until a final solution is reached.

4. Methods for Comparisons

To investigate the effectiveness of the HLRGA, two heuristic approaches have utilized. These two approaches are based on GA which is hybridized by linear programming and called hybrid genetic algorithm (hGA), and simulated annealing (SA). The section presents a brief explanation about the hGA and SA developed for the problem by the authors of the paper.

Require: an upper bound \bar{L} , initial values $\lambda_{t,i}^0 \geq 0$, a sequence θ_v , and N_{iter} .

Ensure: best solution (X^*, Y^*, Z^*, S^*) for production-distribution model

1. Set iteration $\tau = 0$
 2. **While** $|\lambda_{t,i}^{\tau+1} - \lambda_{t,i}^{\tau}| \leq \varepsilon$ for all t, i , and $\tau < N_{iter}$ **do**
 3. Call GA to solve uncapacitated production-distribution model and obtain $L(\lambda^{\tau})$
 4. **If** GA solution is an improved feasible solution to production-distribution model **then**
 5. $\bar{L} \leftarrow$ GA solution of uncapacitated problem {update \bar{L} }
 6. **End if**
 7. Calculate
 - $$\gamma^{\tau} = \frac{\partial L}{\partial \lambda} \quad \{\text{gradient of } L(\lambda_{t,i}^{\tau})\}$$
 8. Calculate
 - $$k = \frac{\theta_v(\bar{L} - L(\lambda^{\tau}))}{\|\gamma^{\tau}\|^2} \quad \{\text{step size}\}$$
 9. $\lambda_{t,i}^{\tau+1} = \max\{0, \lambda_{t,i}^{\tau} + k\gamma_{t,i}^{\tau}\}$
 10. **If** no progress in l iteration **then**
 11. $\theta_{v+1} = \frac{\theta_v}{2}$
 12. **End if**
 13. $\tau = \tau + 1$
 14. **End while**
-

Figure 4. Pseudo code for Proposed Hybrid Lagrangian Genetic Algorithm

4.1. Hybrid genetic algorithm

As is known, when the opened plants and DCs are known on the multi-stage SCN design problem, the problem is reduced to a capacitated transshipment problem (CTP), which is relatively easier to solve by commercial software packages such as LINGO, CPLEX, etc., since it is a linear programming formulation. Based on this property, a GA hybridized with CPLEX (hGA) is developed. In hGA, a chromosome consists of two segments having same encodings. First, a transportation tree between DCs and customers and demands of the DCs are obtained by decoding of the second segment of the chromosome, and the cost of the last stage is calculated. The GA procedure is the same as explained in section 3.1. After determining which plants will be opened using binary encoding of the first segment, the problem for the first two stages is reduced to CTP, and the CTP is solved by CPLEX. The fitness value of the chromosome is the summation of the cost of CTP and the cost of last stage which is obtained by decoding of the second segment of chromosome.

4.2. Simulated annealing

Simulated annealing (SA) is a effective optimization algorithm motivated from an analogy between the simulation of the annealing of solid and the strategy of solving combinatorial optimization problems. In this paper, in order to enhance the exploitation ability of the proposed algorithm, DE is hybridized with a simulated annealing (SA) algorithm. All current solution vectors are improved by using SA.

The applied SA could be briefly introduced as follows: It starts with an initial solution, each solution vector of the current generation, and for each vector a neighbor solution is generated. In the proposed SA, a neighbor vector $N_i = [N_{1,i}, \dots, N_{D,i}]$ for each solution vector (X_i) is generated according to Equation 22.

$$N_i = X_i + rand_j(X_j^U - X_j^L) \times \rho \quad (22)$$

where ρ is used to ensure that parameter values lies inside their allowed ranges in neighbor vector. Let $F(X)$ and $F(N)$ denote the objective function values of the current solution and the neighbor solution, respectively and define Δ as the difference between these objectives; that is $\Delta = F(X) - F(N)$. If $\Delta \leq 0$, the neighbor solution is accepted; otherwise it is accepted with probability equal to $e^{-\Delta/T}$. where T is the temperature parameter such that $T > 0$. At the beginning, the temperature is set at the initial temperature T_0 . Then T is decreased after generations according to the formula $T = \alpha T$, where α is the coefficient controlling the cooling schedule ($0 < \alpha < 1$).

5. Experimental Results

This section gives numerical results on the performance of HLRGA. All algorithms are coded in MATLAB 7 and executed on an Intel® Core 2 DuoE4500 at 2.20 GHz with 2.0GB of RAM. Before the numerical results, information about the test problems and the parameter setting of each algorithm will be given.

5.1. Test problems

Two sets of the test problems are considered in this research. The first set consists of 10 classes of problems called small size problems, and each class contains 10 randomly generated problem instances. Therefore, 100 problem instances are considered for the small size problems. These problems can be solved optimally and they are used to provide a better sense of the performance of the HLRGA. The second set called large size problems includes six classes of problems. Each class of this set contains 20 randomly generated problems, and a total of 120 problem instances are considered as large size problems. This set of large size problems are used to provide an idea of the comparative performance of the heuristic approaches with respect to objective function value. The methods presented in [34] are used to generate some of the tests' data.

The parameter settings of HLRGA, hGA, and SA are as follows: since one offspring is generated by crossover and mutation operators at each generation of the HLRGA and hGA, the crossover rate is set to 0.9, and the mutation is applied to offspring with the probability of 0.15. Based on the preliminary runs, the population sizes of HLRGA and hGA are taken as 50. The initial temperature in SA is set to 1000 in which an inferior solution (inferior by 70% relative to current solution) is accepted with a probability of 0.90. The final temperature is taken as 0.15 such that a solution which is inferior by %1 relative to current solution is accepted with a probability of 0.1%. The best individual of the initial population of the

HLRGA is taken as the initial solution of SA. In order to make a fair comparison between heuristic algorithms, CPU time is chosen as a stopping criterion.

5.2. Computational Results

The parameters of the small size problems are given in Table 1. The problems are described by providing the number of customers ($|P|$), the number of potential DCs ($|N|$), the number of sources ($|M|$), and the number of time horizons ($|H|$). As mentioned in section 5.1, each class of problems contains 20 randomly generated problem instances. To investigate the solution quality of the heuristic approaches, the optimum solution of each problem instance is obtained by CPLEX. The CPU time of each problem instance, which is used as a stopping criterion for the HLRGA, hGA, and SA, is obtained by solving the problem instance with the LH. The last two columns of the Table 1 report the average CPU times for the CPLEX. As is seen in this table, the optimum solutions of the first six problems are obtained in a short time by CPLEX.

Table 1. Small size problems

Problem Class	Parameters				CPU Time (S)
	$ P $	$ N $	$ M $	$ H $	CPLEX
S1	10	5	2	2	3.25
S2	10	5	2	2	8.43
S3	20	5	2	2	7.46
S4	20	10	3	3	16.67
S5	30	5	3	3	87.93
S6	30	10	4	3	213.03
S7	40	10	4	4	723.90
S8	40	15	5	4	1305.11
S9	50	10	5	4	4988.30
S10	50	15	10	6	12895.83

Table 2. Comparison of meta-heuristics for small size problems

Problem Class	Optimality gaps (%)					
	HLRGA		hGA		SA	
	Average	Maximum	Average	Maximum	Average	Maximum
S1	0.00	0.43	0.00	0.32	0.03	0.45
S2	0.05	0.41	0.00	0.24	0.19	0.35
S3	0.13	0.65	0.09	0.44	0.32	0.87
S4	0.34	1.04	0.27	0.69	0.45	0.98
S5	0.86	1.54	0.95	1.43	1.43	1.90
S6	1.14	2.26	1.59	2.98	1.96	3.16
S7	1.88	2.59	2.13	3.22	2.29	3.35
S8	1.94	2.46	2.09	3.18	3.14	3.44
S9	2.62	3.11	3.62	4.26	3.80	4.19
S10	3.19	3.75	4.67	5.52	4.43	6.87
Average	1.215	1.82	1.54	2.23	1.80	2.56

In Table 2, we have reported the summary of results for 10 classes of the small size problems with 20 instances in each. As performance measures, we have used the average percentage gap and maximum percentage gap between heuristic solution and optimum solution. The gap is defined as $100 \times (\text{heuristic solution value} - \text{optimum solution value}) / \text{optimum solution value}$. When the heuristic approaches are compared with respect to average gap over all 10 classes of the problems, it is seen that the HLRGA exhibits the best performance with the average gap of 1.215%. As seen in Table 2, while the average gap between the optimum solution and the HLRGA is less than 2%, the average gaps for the hGA and SA are less than 2%. Also, as seen in Table 2, the average and maximum gaps of the hGA and SA are close to each other. With respect to maximum gap over all 10 classes of the problems, it is seen that the HLRGA is comparable to the hGA.

Table 3. Large size problems

Problem Class	Parameters				
	I	J	K	L	H
S1	100	20	2	5	3
S2	100	30	2	5	3
S3	200	30	4	10	6
S4	200	40	4	10	6
S5	300	40	6	20	12
S6	300	50	6	20	12

Table 3 reports the parameters of the six classes of large size problems with 20 instances in each. As seen in Table 3, the number of customers, the number of potential DCs and the number of sources vary from 100 to 300, from 20 to 50, and from 10 to 25, respectively. Since the problems are very large, it is not possible to obtain their optimum solutions by CPLEX. As observed in Table 1, the average CPU times in CPLEX for the problem classes, where the number of product is 3, are higher than for the problems having two products. This shows that one of the important factors affected on the solution time of the problem instances is the number of the product.

Table 4. Comparison of meta-heuristics for large size problems

Problem Class	Optimality gaps (%)					
	HLRGA		hGA		SA	
	Average	Maximum	Average	Maximum	Average	Maximum
S1	2.43	4.63	4.23	5.98	4.68	6.78
S2	2.25	4.12	4.59	6.32	4.56	6.96
S3	2.89	4.76	5.22	6.88	4.68	7.43
S4	3.23	5.14	5.89	7.33	5.37	7.82
S5	3.53	5.64	6.19	7.47	5.89	8.37
S6	3.41	5.60	6.48	7.68	5.84	8.63
Average	3.20	5.22	5.84	7.26	5.39	7.98

Table 4 shows the average and maximum gaps of the proposed meta-heuristic approaches. Since the optimal solutions for large size problems are not known, the gap is defined as $100 \times (\text{heuristic solution value} - \text{lower bound}) / \text{lower bound}$. The lower bound is the best value of the objective function found by any of algorithms (i.e., HLRGA, hGA, and SA). When the

heuristic approaches are compared with respect to average and maximum gaps over all six classes of the problems, it is seen that the HLRGA outperforms the other heuristics. Its average and maximum gaps are between 2.25% and 3.53%, and 4.12% and 5.64%, respectively. While the average and maximum gaps of the SA over the six classes of the problems are 5.39 % and 7.98%, respectively, these values are 5.84% and 7.26%, respectively, for the hGA. When the problem size increases, it is seen that the performance of the SA drastically decreases.

Furthermore, the proposed model has been evaluated by using data from an industrial real-world case in Iran. The conventional production and distribution strategy used by case is to maintain a constant work force level over the planning horizon, and fluctuated demands can then be met by using some combination of inventories, overtime. However, the expected performance was unable to achieve because of drawbacks on the current experiential method focus on a single component of the overall system, for example procurement, production, transportation, warehouses, or scheduling, despite the integration of these components in a single supply chain, and evaluation comparisons can only be done for specific plans under specific conditions and indication is vague for the optimum plan.

Alternatively, the decision maker would apply a mathematical programming method to develop an integrated production-distribution planning decisions plan for the industrial case. The planning horizon is 12 months. The forecasted demand fluctuates a lot over the planning horizon because seasonal variations. The product model includes 27 types of products. Also it comprises 4 sources and 160 customers.

In order to compare the quality of heuristic solutions obtained by the HLRGA with that of optimal solutions if they are available or feasible solutions obtained after running CPLEX for 10 h (i.e. 36,000 s), we have conducted the additional computational experiments. It is seen that CPLEX could not reach to optimal solutions for the problems after running 10 h. The average and maximum gaps based on the feasible solution of the CPLEX for this real case which solve 10 times are 3.38% and 5.59%, respectively. These results support the fact that the HLRGA can be used as an effective and efficient tool for designing the supply chain networks in real world case.

6. Conclusion

This work develops an integrated production distribution system in real-world industrial case which is a multi-source, multi-stage supply chain network design problem in dynamic environment. In this paper, a hybrid lagrangian relaxation genetic algorithm (HLRGA) is proposed for the candidate problem, which is a NP-hard problem. In the proposed algorithm the genetic algorithm (GA) is incorporated into the lagrangian relaxation (LR) method to update the lagrangian multipliers and improve the performance of LR method. The effectiveness of the HLRGA was investigated comparing its results with those obtained by CPLEX, hybrid GA and simulated annealing on two sets of test problems consisting of a total of 320 instances. Experimental study showed that the HLRGA found better heuristic solutions than the other heuristic approaches and reached the good heuristic solutions with lower computation time when compared with CPLEX. This is particularly attractive in large-

scale systems. Future research is achieved on consideration of this modeling under uncertainty conditions with other critical SC problems such as vehicle routing, carriers loading, etc.

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