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Modeling Relationship Maps for The Factors of Purchasing Management System According to Selected Key Drivers Using Fuzzy Cognitive Maps

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Abstract

Strategic management is the philosophy of the creation which provides a goal, a plan and a model for the competitive advantage. Companies define their own goals and generate the plan for goal according to this management philosophy. However, company can utilize successively from this philosophy so long as it is able to be adapted to all management systems such as product, inventory, manufacturing and etc... Purchasing management system is the one of them. It is a basic management unit where decisions, goals and plans are structured according to production and customer requirements which give the competitive advantage to each company. All of them can be managed strategically by being focused on the appropriate purchasing conditions including low-cost, high quality, and on-time delivery. In this study, we will determine variables and the relationships between them which affect in achieving the strategies of the company in terms of purchasing management system. Fuzzy cognitive mapping method will be selected in order to find them out because this method creates a map by using some strategies for system. The results will be presented at the end of the study.

Keywords: Purchasing Management System, Fuzzy Cognitive Map, Relationship Maps for Cost, Quality, and Delivery Drivers

1. INTRODUCTION

Many companies supply needs about material, service, and knowledge from outsource because they need to perform basic and support activities and to manage them. This is called the purchasing system. In this system, requirements are bought at an optimum price and a suitable method of payment according to how the product standards are defined. Besides, the purchasing management system is a structure which determines needs, makes a decision about appropriate suppliers, and manages all processes belonging to purchasing system. The basic aims and objectives for this management system can be presented as follows [14,30];

1. Ensuring the continuity of flow between material, supply, and service
2. Preventing the loss of time during material supply
3. Finding a lot of capable and reliable suppliers
4. Buying part or service which has lowest total cost

Some key questions can be produced because above objectives are fulfilled and product and service flow from producer to customer is provided constantly. These are as follows:

1. How much can the profit of company be increased by decreasing the total cost of the product when the purchase price of raw material is managed effectively? (cost savings)
2. What extent is the quality of raw material important because product quality is a degree as much as customers expect? (Quality)
3. Is the product cost affected because the product will be delivered in the range of dates offered by the customer if raw material is not received on time? (On-time Delivery)
4. Which factors are important to determine purchasing performance? (Performance Management)

Performance system, called as purchasing performance system, can be developed to solve the above questions. This is defined as quantitative and qualitative assessments to perform the operational objectives that company links with purchasing validation and effectiveness [19]. Stock and Lambert (2001) defined twenty performance data to evaluate purchasing performance. These includes in purchasing price, price variation, rate of defective, order amount like this [30]. These data resources which build up the internal structure of purchasing are used particularly in the selection phase of choosing a suitable supplier. Van Weele (2002) described four dimensions including price/cost, quality, logistic/time, and organizational in order to measure and evaluate the

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activities of purchasing. While organizational dimension was identified as a qualitative measurement related to human resources and organizational structure in any company, the other three sources were quantitative dimensions measured by variables in the purchasing process [33].

In this study, a model will be developed in order to figure out which factors affect purchasing performance system. Also it searches out a solution about basic problems in this system. Factors and dimensions will be selected from not only internal sources pointing out studies performed by Stocker and Lambert, and Van-Der Weele but also external source from other management systems affecting purchasing management system. Because purchasing performance can be achieved by executing specific internal and external purchasing practices, in addition to other internal and external performance drivers [5,6]. Fuzzy cognitive mapping methods will be used to calculate the influence degree among factors. So, previous studies about purchasing performance system and the fuzzy cognitive map method will be reviewed. The second section shows the reviews. In the third section, results of application will be given after describing comprehensive framework of this study. Consequently, conclusion will be drawn.

2. LITERATURE REVIEW

In this section, a detailed literature review on purchasing performance system and fuzzy cognitive maps is presented in sub-headings, respectively.

1. Purchasing Performance System

Keegan et al (1989) developed a general framework to evaluate system performance in industry. Performance measurements of model consisted of design, materials, manufacturing cost, cost position in competitive, relative R&D expenditure, design cycle time, on-time delivery percentage, the number of new products, the quantity of loyal customers, the number of customer complaints, and market share [16]. Fitzgerald et al (1991) focused on financial performance, competitiveness, flexibility, resource utilization, and innovation to develop a general performance measurement framework [12]. Bourne et al. (2000) developed a more comprehensive model framework based on four perspectives. These are respectively financial, internal, customer, and innovation & learning. Financial perspective would cover profitability, value added /employee, order initiate and invoiced sales. Internal perspective has five different resources; order quality, forecast accuracy, supplier on-time, rework, and warranty returns.

Customer perspective was composed from customer complaint, on-time delivery, new customers, enquiries, quotation, sales activity, and order conversation rate. Finally, innovation & learning perspective occurred appraisals-on time, employee communication, surveillance stage gates, and on-time training needs met from occurs [3].

Pohl and Köhl (2011) evaluated a purchasing performance including five hypotheses based on five different role plans. These role plans include strategy measurement, measuring performance, influence behavior, learning and progress, and communication. They used four measurement variables to evaluate hypotheses and plans: cost, quality, delivery, and flexibility [24]. Saranga and Moser (2010) used key performance factors and mid-level output factors to figure out purchasing and supply performance. Key performance factors consisted of the number of strategic buyers, the quantity of transactional buyers, and the number of suppliers, while mid-level output factors occurred cost savings, cross-functional collaboration, and supplier performance [28]. Easton et al (2002) benefited from four input and two output sources to overcome the technical shortcomings of purchasing system and to measure purchasing performance. Inputs were operating expense, professionals, administration, and active suppliers. In addition, main output sources included purchase dollars, and percent of company savings [9]. Gonzalez-Benito (2007) utilized cost, quality, delivery, flexibility, and competing priorities to evaluate performance in strategic purchasing objective and to determine purchasing capabilities [13]. Ellram et. al (2002) proposed hypotheses by focusing on organizational success to research the link between purchasing and supply management and the corporation' s success. These hypotheses were evaluated according to cost, product/service validation, price, technology affecting product life cycle, and standard sizes [10]. Emiliani et al (2005) identified alternative approaches and tactics to improve purchasing performance and to satisfy objectives of the company by focusing on purchasing price variation (PPV).
The study stated that purchasing and supply management organizations were evaluated with many different measurements like purchasing price, on-time delivery, quality, inventory price, etc… Also, they suggested that measurement system should be structured a cost-oriented system [11].

Pagell (2004) developed a comprehensive model to provide integration between purchasing and logistic system. The model covered eight integration factors and four strategies. These strategies were business, logistic, purchasing, and manufacturing levels. Three strategies were focused on quality, delivery, and price measures, while purchasing strategy was based only on price factor [22]. Baier et al (2008) designed a model by using purchasing, competitive priorities, purchasing practice, financial performance, and business strategy. The basic variables of each strategy were focused on cost, quality, technology, innovation, and management. However, purchasing practice strategy consisted of cost, quality, and innovation [2].
Cousins et al (2006) investigated the relationship between the purchasing configuration and organizational performance. Data sources which were used to evaluate this relationship were product quality, delivery speed, delivery reliability, flexibility of production, return on investment, return on sales, profit growth, return on total assets along

with information from upper management, suppliers, and purchasing professionals [7]. Narasimhan and Das (2011) divided performance factors as a three basic structure to investigate the relationship between purchasing practice and manufacturing performance: first order critical factor of achievement (CFA), and second order CFA and manufacturing performance. These factors involved buyer-supplier relationship development, supply base leveraging, supplier performance evaluation, and purchasing integration factors. Cost, quality, time, and delivery measures were used to find out performance levels of these factors [20].

Das and Narasimhan (2000) tried to identify purchasing competence and to investigate the relationship between the priorities of different manufacturing models and purchasing competence. Relationships were based on manufacturing cost, quality, and delivery together with new product design and customization [8]. Narasimhan et al (2001) attempted to identify the elements which designated purchase competence. This competence was examined in terms of five dimensions: empowerment, employee competence, effectiveness-tactical interaction, buyer-seller relationship, and interaction management effectiveness-NPD. Besides, these dimensions involved fifteen different measurements such as job security, sharing cost saving with suppliers, performance evaluation related to quality improvement, etc… [21].

We concluded that any performance system, especially purchasing performance system, should be focused on cost, quality, and on-time delivery, after all studies were examined. So, these dimensions were selected to develop a model and to determine drivers affecting purchasing management system.

2. Fuzzy Cognitive Mapping

Fuzzy Cognitive Map (FCM) is modeled as a single layer network, which the nodes of relationships between concepts are presented by the fuzzy weights [23]. Concepts are defined as the modeled attributes which consist of key factors, input, output, variable, events, actions, goals, and trends within the system [6, 34] and present the behavior of the system [6]. Each concept is represented by node. These specified nodes are indicated by C notation. Experts give the fuzzy weights in the range of [-1;+1] to produce the causal relationships between them after both concepts and nodes are determined. (-1) identify a negative relationship, while (+1) present a positive relationship. Weights introduce by wij which describe relationship between i and j node [6,17,18,29,31,32,34,36]. Three types of relationship exist;

1. $w_{ij}>0$, there is a positive and direct relationship between Ci and Cj nodes. The value of Cj increases, when the value of Ci factor increases, or vice versa.
2. $w_{ij}<0$, there is a negative and inverse relationship between Ci and Cj nodes. The value of Cj increases, when the value of Ci factor decrease, or vice versa.
3. $w_{ij} = 0$ indicates that there is no relationship between the two factors.

Weight values are calculated according to evaluation scores given by experts. So, each FCM study is conducted with a different number of experts. However, the ideal number of experts is suggested in the range of 5-18 [25, 27]. Experts are selected from people who can describe structural behaviors in the system. They decide the concepts and the relationship scores between each other by observing system [6]. Each expert has a different perspective so a number of different maps are obtained and their maximum value equals the amount of used specialists. If you use fifteen experts, you can attain fifteen different maps. Then, the values of relationships on each map is converted into a single correlation score in the range of [-1; +1] by using mathematical methods. Thus, a common map is created. In this study, we use the fuzzy cognitive map method in order to determine the basic performance criteria for the purchasing management. The next section defines our conceptual model showing how we use this method.

3. A RESEARCH MODEL

Our conceptual model is made up of three phases as shown in figure 1. First phase includes system analysis stages. This system consists of three consecutive steps; defining strategic targets, investigating internal and external processes of system in accordance with targets, and selecting data sources or performance drivers in these processes. The Second phase is called design and evaluation. Drivers, called as nodes, determined in the previous phase are used to design a survey before experts are selected in order to get their scores. They will carry out their assessments in two ways. First, relationships between factors are interpreted with scores from 0 to 4 points. Second, they are re-evaluated in the form of positive (+) and negative (-) correlation. The information of these points is given in Table 1.

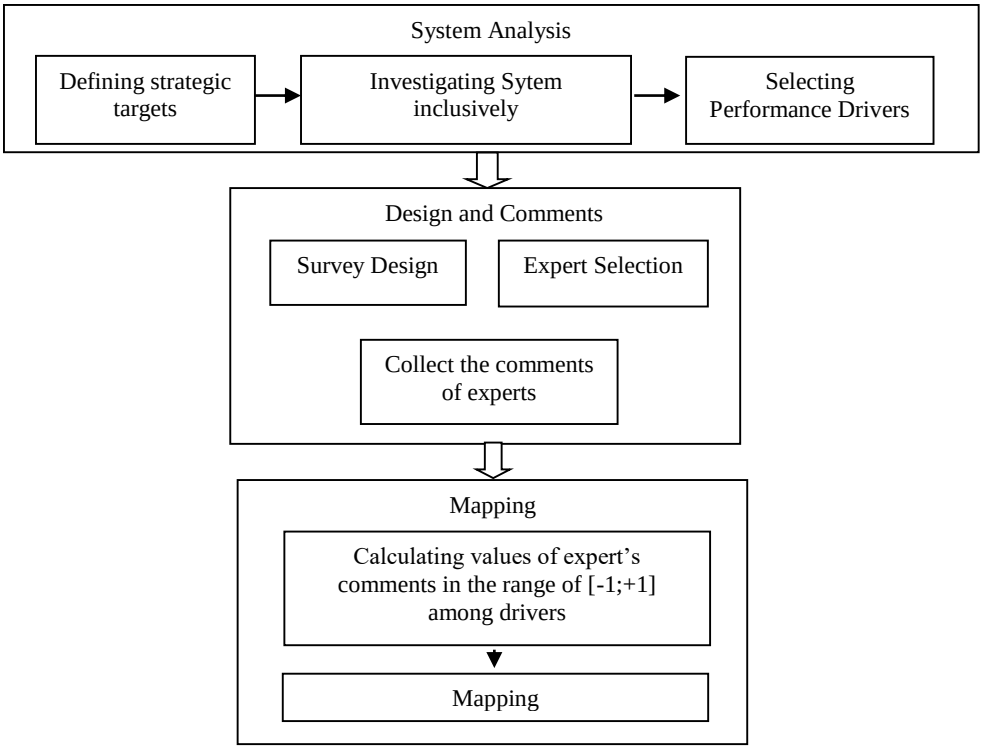

Fig 1. Conceptual Model

Table 1. Points and Definitions

Point	Definition
0	No relationship between nodes
1	Weak relationship
2	Medium relationship
3	Strong relationship
4	Very strong relation

The last phase of the model includes mapping stages. The fuzzy values presented by "w_{ij} (Weights between nodes)" are calculated via expert opinions on the surveys by using eq.1. These scores are converted to linguistic terms shown in table 2. All of them show positive relationship but negative ones with same scores define inverse relationship. The different views of the experts are combined with these calculations. Thus, a single map with linguistic expression is obtained.

Equation.1

$$w_{ij} = \frac{\sum_{i=1}^{K}[A]_{ij}}{s \times K} \times r$$

$[A]_{ij}$= Scores of expert
s= The total number of different scores in the range of [0-4] in j column
K = The number of experts
r = Relationship status = $\begin{cases} 1 & Total\ number\ of\ (+) > Total\ number\ of\ (-) \\ -1 & Total\ number\ of\ (+) < Total\ number\ of\ (-) \end{cases}$
i = The drivers or nodes selected the row i = 1,2,…,K
j= The drivers or nodes selected the column j = 1,2,…,K

Table 2. The Ranges of Fuzzy Relationship

The Ranges of Relationships	Definition
0≤wij≤0,2	Non
0,2001<wij≤0,4	Weak
0,4001< wij≤0,6	Middle
0,6001< wij≤0,8	Strong
0,8001< wij≤1	Very Strong

4. APPLICATION

This section represented application of conceptual model and all results. Each phase was described step by step.

4.1 System Analysis

System analysis was composed of three stages. First of all, strategies about purchasing management system were to be determined. Strategies were configured by using these dimensions because we decided three different dimensions in order to measure the performance of the purchasing management system in the result of literature review. They were as follows;

1. Purchasing cost is leverage for production cost.
2. Raw material quality is a factor impacting product quality and reliability.
3. The delivery competence of suppliers depends on delivery satisfying on due date.

Second stage was composed of internal and external system analysis for purchasing management system. Figure 2 shows the analysis example of connection between purchasing management system and other management systems. We

reviewed not only SAP (Systems, Applications and Products in Data Processing) [37] and IAS (Industrial Application Software) Enterprise Resource Planning Program [15] but also PHD dissertations [14,26,35], books [19,30,33] and the processes of some company [38,39] about purchasing process management.

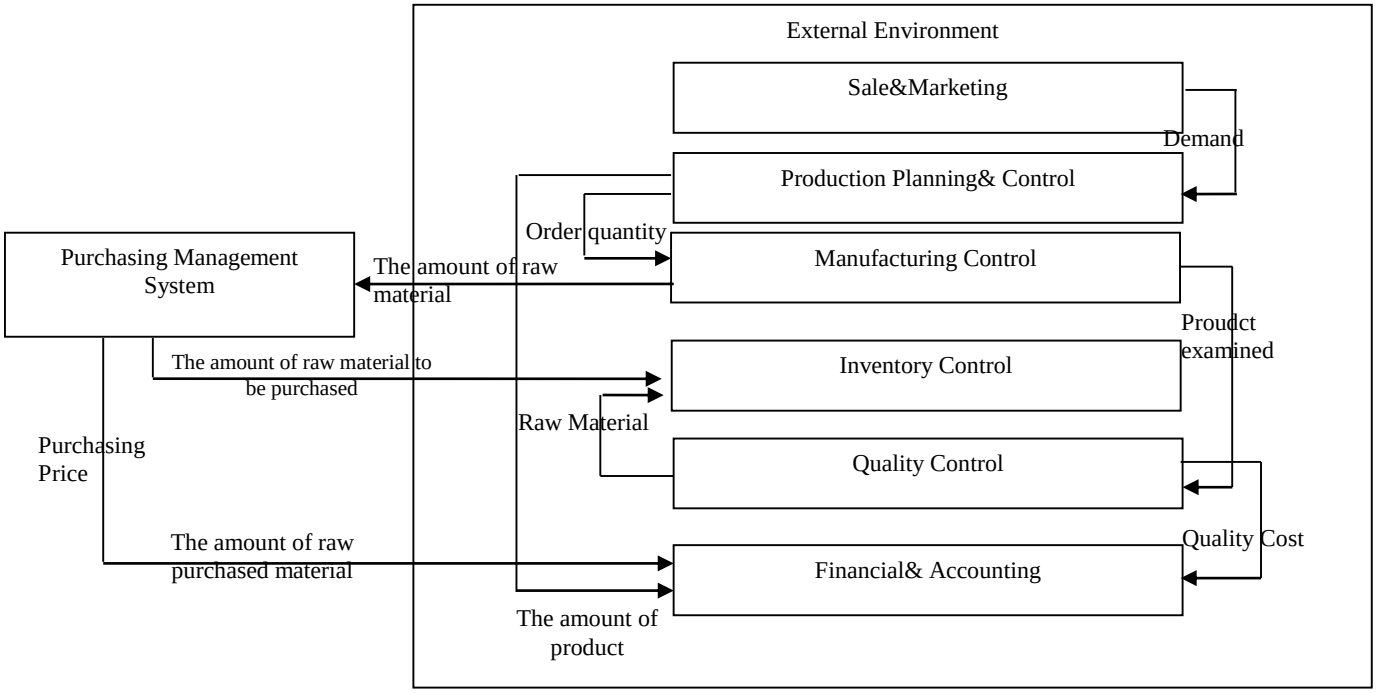

Fig 2. The Example of Analysis between Purchasing Management System and External Environment

As a result of all three stages, eighteen different performance drivers were determined from raw material quantities which will be purchase to product due date.

4.2 Design and Expert Evaluation

This level consisted of two stages following each other. The first stage has two parallel different stages; expert selection and survey design. Experts were selected from engineers who work at purchasing and production departments in Istanbul, Bursa, Kocaeli, Izmir, and Sakarya where they have main manufacturing industries. Also, experts work for different industries from the automotive industry to textile industry. In the parallel stage, the survey was designed as a matrix structure that the column and row sizes of it were eighteen which is same with performance drivers. This survey was sent to twenty six people and explained how to evaluate the survey by one to one interviews. The numbers of surveys returned from the experts were fifteen. We passed the last level because this amount is the maximum amount which was mentioned in the study [25,27].

4.3 Mapping and results

This phase was the last one. Our purpose was to get three maps for each performance size. So, all points were transformed to the ranges of definitions by using formula 1 and also linguistic values. The couples of weak and middle relationships were eliminated. All maps in the result of elimination were drawn according to cost, quality, and delivery (time). These are respectively Fig 3, Fig 4, and Fig 5. In the figures, the colors of arrows demonstrate the types of relationships. While red arrows remark positive relations, the others are negative relations. Also, dashed lines indicate strong values while the others represent very strong values.

The relationship map shows sub-indices C and i and j. Specified nodes or factors on row (C_i), specified nodes or factors on column (C_j) defined respectively.
When Figure 3 is analyzed, we noticed that a total of twenty-seven relations may affect the cost performance of purchasing. Twenty-one of them are in the strong status while six of them are in the very strong status. Also, three relationships are in the mutual position. So, these nodes which have them are both receiver and transmitter. These are The quality properties of raw material (C14)- the quality properties of product (C15), C14- the quantity of product returned by customer because of raw material (C9) and the stock quantity of raw material (C10)- the quantity of purchased raw material (C1). Moreover, nodes which have the dense relationship networks can be listed C14, C9, and C1 in descending order. While C1 and C9 nodes are generally the receiver, C14 is the transmitter. They can be used also to determine only the purchasing cost performance. There are only three nodes playing role of receiver position. These are the stock quantity of product (C11), delivery time of raw material (C5), and the contract properties of purchased raw material (C16).

C5 is associated with the situation of materials on production line (ready, processing, delay) (C4) and the order quantity of product (C7). The Directions of the relations are direct. C5

has some characteristics while C4 and C7 have some properties for product. Besides, we did not understand how experts decided relations between them. Calculations for a product can be confused if raw material is not delivered on time. We expected that directions of arrows for these relations are transmitter rather than receiver. Second relation network between C11 and The quantity of sold product (C8) reflect the impact on the performance of overall cost. Finally, C16 is associated with C1 and C14 and these relationships are interpreted by thinking of directions of them as follows; "If the quality of the raw material and the product is wanted highly by producer, then company can suffer increases in costs."

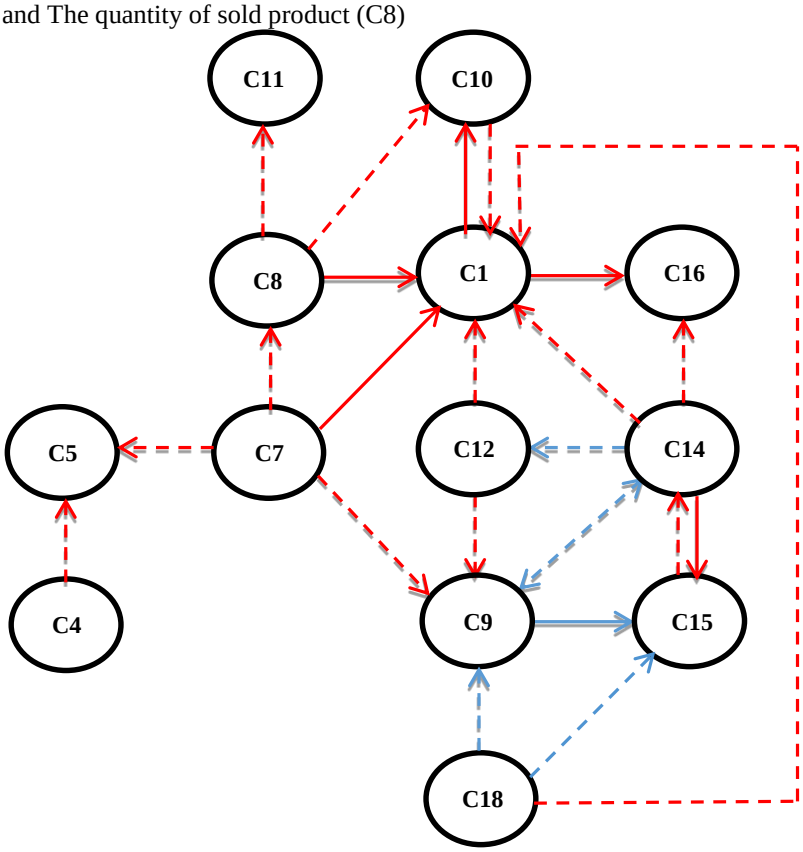

Fig. 3. Relationship The Map for Cost Driver

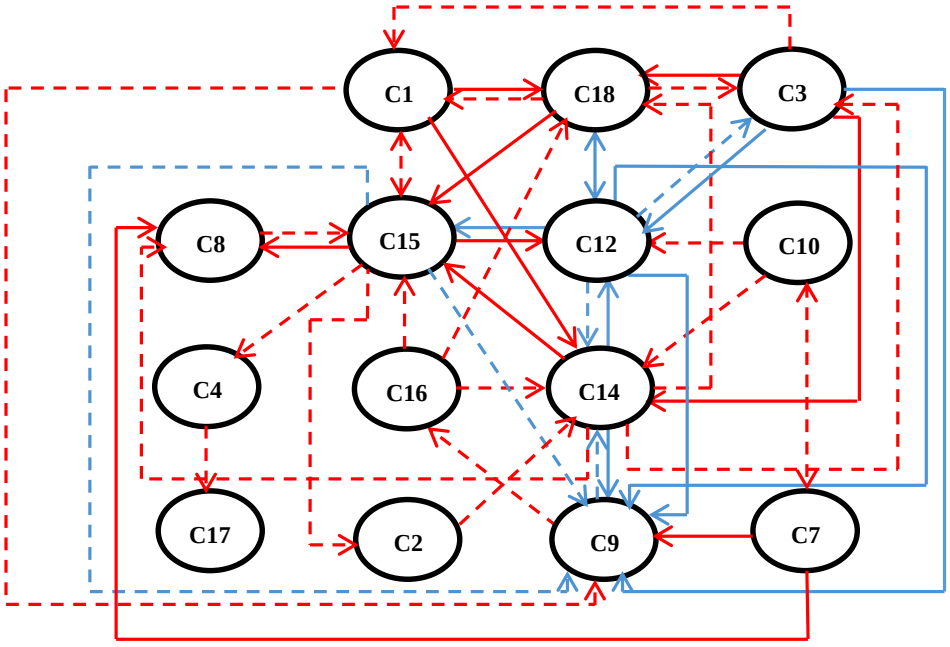

Fig. 4. The Relationship Map for Quality Driver

When map (Fig 4) was examined, there are forty-three relationships and sixteen of them are in the high relationship status while the remaining twenty-seven are in the very high relationship status. This map is the crowded mesh network structure. This reason is assumed that the measurement of performance variables related with quality varies from person to person. Only one node is in a receiver position in an environment where it has a lot of relationships. This node called as C4 and it has also relation with the delivery time of product (C17). However, we think that it is associated with the general quality of the company because both nodes are related to the properties of product. The network structure of maps prepared for other two performance drivers are clearly identified while those for this driver cannot be defined very easily. Also, seven nodes have an extremely more crowded network as transmitter and receiver than others. These are enumerated C14, C15, the quantity of raw material returned by company (C12), the quality properties of supplier (C18), selection rate for suppliers (C3), C9 and C1 in descending order. C15 demonstrates the general quality performance of company, while other nodes affect the quality performance of purchasing because they indicate situations which occur due to problems in purchasing management.

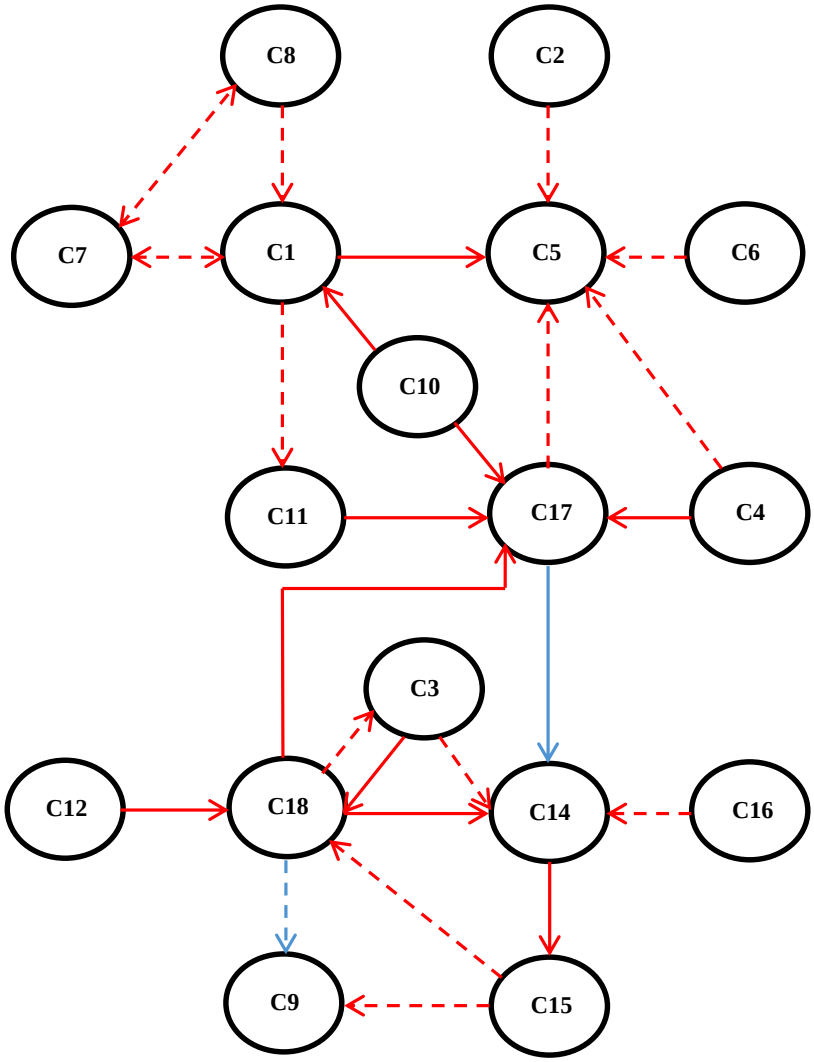

Fig. 5 The Relationship Map for Delivery Driver

This map (Fig 5) shows that there are thirty relationships which affect purchasing and overall performance of company in terms of delivery. Eleven relationships are very strong in position, while nineteen of them are strong in position. In addition, the types of three relations are in transmitter and receiver position. When all nodes are examined, we noticed that five nodes are extensively in both receiver and transmitter position. These are C1, C5, C14, C17 and C18 respectively. While three nodes show the delivery performance for purchasing, one node is related to the product. However, C5 and C9 nodes are only receivers. C5 has relationships with six nodes. These are C1, quantitative properties (C2), delivery type (C6), C4, and C17. When we looked at the properties of them, we observed that the decisions and variations are related with the amount of purchased raw materials, desired specifications for raw materials, delivery type, production conditions, and delivery time that caused especially changes in the delivery quality.

When the conditions of these nodes are satisfied, then the delivery performance of company will be increased. C9 has relationships with C15 and C18. We did not understand what experts. thought about these nodes and delivery performance because all of them are related with quality performance.

5. CONCLUSION

Purchasing management system is the primary stage for production processes. This system takes on a task as leverage for general management and especially production management system. So, any decision change on variables in purchasing management system will affect the entire system. All management system performances including purchasing management system can be measured and controlled by performance drivers. These are cost, quality and also time or delivery in general. In this study, we focused on generating relationships between variables of purchasing system by considering these drivers. We chose the fuzzy cognitive mapping model as a solution model and tried to create a rule map and network for each driver. We found that the rule map for quality is more complex rather than the maps for the other drivers. We also discovered that the quantity of product redesigned (C13) variable does not have any relationship network in all maps. We decided that this variable is not important for both drivers and purchasing system. Moreover, thirteen nodes for cost, fourteen nodes for quality, and seventeen nodes for delivery are more important than the other variables. We estimated that making a decision on a these variables which are very necessary for each driver affect the purchasing performance. When maps were prepared in this study, limit was made only in terms of department worked. For this reason, we considered that maps were more complex than they should be, because each sector owns a lot of different variables. So, we did not figure out one relationship in the cost map and two relationships in the delivery map. There are two reasons. The first reason is that there should not be restrictions in terms of industrial sector, while the second reason is the number of experts who were used in this study. Maps were got by using the numbers of experts which is close to upper limit number which was referred in [25,27] article. In future studies, industry-specific maps can be produces. Second, the performances of both maps can be compared in terms of functionality by producing another map a smaller number of experts.

In this study, the opinions of experts were based to obtain maps. Transaction loads in ERP program of selected performance variables were not considered. For this reason, a more functional map can be made by comparing both expert and transactional loads. This approach will be addressed in terms of the subject of database optimization.

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