A Road Map for Knowledge Management Systems Design Using Axiomatic Design Approach

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Abstract. Successful design and implementation of knowledge management systems have been the main concern of many researchers. It has been reported that more than 50% of knowledge management systems have failed, therefore, it is required to seek for a new and comprehensive scientific approach to design and implement it. In the design and implementation of a knowledge management system, it is required to know 'what we want to achieve' and 'how and by what processes we will achieve it'. A literature review conducted and axiomatic design theory selected for this purpose. For the first time, this paper develops a conceptual design of knowledge management systems by means of a hierarchical structure, composed of 'Functional Requirements' (FRs), 'Design Parameters' (DPs), and 'Process Variables' (PVs). The intersection of several studies conducted in the field of knowledge management systems has been used to design the knowledge management model. It reveals that six essential bases of knowledge management are organizational culture, organizational structure, human resources, management and leadership, information technology, and the external environment of the organization; that are represented as top DPs in the structure of the model. These essential factors are decomposed to lower levels by means of zigzagging. The model implemented in Tehran Urban and Suburban Railway Operation Corporation (TUSROC) and the results were very promising. The most important result of this study is a roadmap to design successful and efficient knowledge management systems.

1 Introduction

Nowadays, more than ever managers and researchers realize that sustainable competitive advantage of organizations and companies stems from scarce and valuable resources such as information, knowledge and organizational procedures, which are not completely mimicked and alternated [1]. 'Knowledge management' (KM) is a series of activities, initiatives, and strategies that companies use in creation, storage, transfer and application of knowledge to improve the organizational performance [2]. Despite, the investment growth in the KM area, due to a lack of a roadmap to implement the KM activities, this investment in the mind of managers has become the fad and have additional costs [3].

Knowledge management seems very simple, but organizations that are trying to become a knowledge-based organization, facing a lot of difficulties. There are no available specific guidelines for the implementation of various methods and concepts of knowledge management [4]. Failure of 50% to 80% of knowledge management implementation projects [5, 6] is the result of (i) lack of knowledge management strategy aligned with organizational strategy; (ii) lack of an appropriate implementation procedure. Considering both lacks, the main questions are that: what knowledge is required for the organization? And how acquire it to achieve competitive advantages and sustain them?

One of the most powerful tools based on a scientific and systematic approach that can answer the above questions is the 'Axiomatic Design' (AD) Theory.

AD asks the designer to develop functional requirements in various aspects of system design systematically and defines the appropriate tools and processes to satisfy them. The separation of 'What' and 'How' in the AD results in flexibility, which is its great advantage versus other design methods [7]. On the other hand, the AD approach during the design process of a new system, based on the mapping process of one set of variables to another [8]. Hence, AD is an appropriate tool for current assessment and changes in processes.

This article uses Axiomatic Design Theory to design a 'Knowledge Management System' (KMS) based on organizational strategies. For this purpose, presents a roadmap to clarifying the objectives of knowledge management and considers the factors influencing on knowledge management system goals. This roadmap provides the appropriate Functional Requirements (FRs), Design Parameters (DPs), and Process Variables (PVs) in various stages of design and implementation to reduce the failure probability. The knowledge management system based on the Axiomatic Design approach is

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simple, fluent, comprehensive, practical, and step-by-step methodology.

2 Principle of Axiomatic Design

Suh [9] states that the ultimate goal of Axiomatic Design is to establish a science base for design and to improve design activities by providing the designer with a theoretical foundation based on logical and rational thought processes and tools. The design is an interplay between 'what we want to achieve' and 'how we will achieve it'. To systematize the thought process involved in this interplay, the concept of domains that create demarcation lines between various design activities is a foundation of axiomatic design. The world of design is made up of four domains: customer domain, functional domain, physical domain and process domain [10].

The attributes desired by customer needs (CNs) are sometimes difficult to define or vaguely defined. These needs are mapped into functional requirements (FRs). This must be defined without ever thinking about something that has been already designed or what the design solution should be. After defining the FRs in functional domain, the next step is the imagination of physical parameters in the physical domain to satisfy the functional requirements. Then, the design enters the process domain. The process variables are selected to satisfy the DPs. Design activities from customer requirements to functional requirements is named conceptual design and from functional requirements to the physical domain is called product design and eventually, from the physical domain to process domain is named process design [10].

One advantage of AD is the hierarchical structure of it, that allows for the designer to deal with design complex issues easily. In other words, by reciprocating motion (Zigzaging) between the different design domains, we create hierarchies for FRs, DPs, and PVs in each design domain (See Fig. 1).

In order to mapping be satisfied between domains, two axioms must be followed:

Axiom 1: The Independence Axiom
Maintain the independence of the functional requirements (FRs).

Axiom 2: The Information Axiom
Minimize the information content of the design.

Mathematically, the set of independent FRs could be considered as a vector **FR** with m components. In the same way, the DPs may be treated as a vector **DP** with n components.

Thus the design process in which the relationships of FRs and DPs are determined may be expressed as

$$\{FR\} = [A]\{DP\} \tag{1}$$

where A is the design matrix. Each element of design matrix, A_{ij}, may be expressed as

$$A_{ij} = \frac{\partial FR_i}{\partial DP_j}$$

So the independent design is shown by a diagonal matrix where diagonal elements are not zero, i.e:

$$A_{kk} \neq 0$$
$$A_{ij} = 0 \ , i \neq j$$

Similarly, the relationship of DPs and PVs are defined as

$$\{DP\} = [B]\{PV\} \tag{2}$$

According to the Eqs. (1) and (2), we can deduce the relationships between FRs and PVs as

$$\{FR\} = [A] * [B]\{PV\} \tag{3}$$

"Each component of the FR–DP–PV relationship must be uncoupled if the overall relationship is to fulfill the Independence Axiom" [8].

If the design matrix is diagonal, we have an uncoupled design. A design with triangular matrix is called a decoupled design. Independence Axiom is dissatisfied with coupled designs and in order to decouple such designs, some changes in the FRs and DPs are needed. If the DPs of a decoupled design are ordered in a special manner, the Independence Axiom is satisfied.

3 The principle of knowledge management

There is no specific definition for KM that all agree with it globally. A common problem in the definition of knowledge management is due to a wide range of knowledge. Knowledge management was initially defined as the process of applying a systematic approach to the capture, structuring, management, and dissemination of knowledge throughout an organization to work faster, reuse best practices, and reduce costly rework from project to project [12]. Dalkir [13] defines that "Knowledge management is the deliberate and systematic coordination of an organization's people, technology, processes, and organizational structure in order to add value through reuse and innovation".
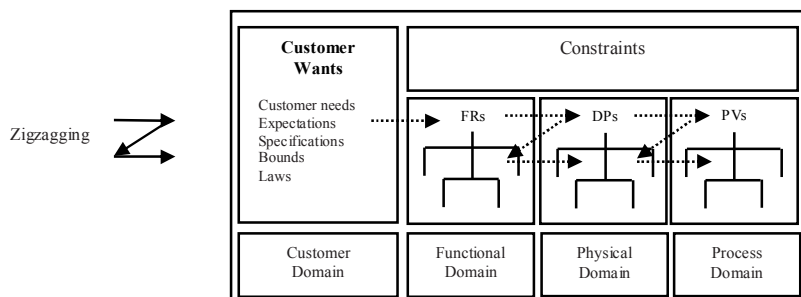

Fig. 1. Various domains of design in AD theory (enhanced from [11]).

In the traditional approach, the attractiveness of selected industry was a most important competitive advantage against competitors. But nowadays with increasing the uncertainty and dynamism in organizational environments, the new strategic researches have been focused on the 'structure - behavior - performance' model as a key competitive advantage that has led to the internal landscape called 'source-oriented'.

Knowledge is a most important strategic resource for companies in the 21st century. On the other hand, since the rate of failure of knowledge management projects is remarkable, identification of success critical factors of knowledge management can help organizations in needs assessment, planning, and implementation of knowledge management projects to reduce the failure probability. The knowledge management system is a sophisticated combine of technological infrastructure, organizational structures, organizational culture, knowledge, and people. The main objectives of a knowledge management system include:

1) Knowledge capture;
2) Improve knowledge access;
3) Enhance the knowledge environment;
4) Manage knowledge as an asset.

For knowledge management, various models has been offered by different scholars. Some of these models have focused on knowledge management activities such as the creation or transferring of knowledge, and the other models have considered a cycle of knowledge management generally and cover the various activities associated with knowledge. However, there is no knowledge management model which all agree with it.

4 A knowledge management system design using AD theory

In recent decades, extensive studies are conducted on various aspects of knowledge management systems. They cover design and implementation techniques with diverse methodologies and modeling. However, the Axiomatic Design methodology has been used by a few researchers.

Evrim Yasar et al. [14] in 2005, first began to design a knowledge management system based on the axiomatic design approach. They decomposed the main FR in three levels of functional requirements (FRs) and design parameters (DPs). This study is important because they are pioneers in applying AD theory in KMS design, however, in their study the effective factor of the knowledge management system have not been considered comprehensively.

The second study has been provided by Brown [15] in 2007. In this work, a knowledge management system has been designed based on axiomatic design principles with an overview in two levels of functional requirements (FRs) and design parameters (DPs). This study, same as the previous case, does not consider a detailed system design.

The third study, in 2013 by Hao et al. [16] entitled 'Knowledge Services In Campus: The Application Of Axiomatic Design'. In this paper, they present the knowledge services (KS) in a university setting. Hereby, they propose a tool, namely 'Knowledge Board' to achieve KS and support the knowledge sharing. This knowledge board has been designed and realized based on AD principles. Also, a case study has been conducted to exemplify the process of using AD to design knowledge services within a university environment.

As mentioned above, the previous studies have some shortcomings. Firstly, the factors affecting on knowledge management are not covered from various aspects. In other words, these factors have not been considered in functional requirements (FRs) of knowledge management system comprehensively, and secondly, for satisfying the design parameters (DPs), the process variables (PVs) have not been provided. That means the needs, how and by what processes must be satisfied have not been considered.

The advantage of the current study is that the design of the knowledge management system has been considered with the critical factors of KM comprehensively. Also, this study with respect to the objectives and strategies of the organization tries to answer the fundamental questions like: What approaches can help organization to achieve competitive advantages? How the organization can choose the route and processes to be able to apply the knowledge management system to achieve its own goals?

According to the AD fundamentals, we present the hierarchical structure to model the design processes of KMS. This structure is developed in a top-down direction, but for the implementation practices, we act based on a bottom-up pattern. The structure of the model of a knowledge management system is illustrated in Fig. 2. The top level of the structure contains CNs, the ultimate goal of knowledge management systems. The next level is the conceptual notions of the knowledge management paradigm, formulated as FRs. The third level contains principles, explaining parameters that affect conceptual notions and formulated as DPs in the given model. The bottom level is methodologies, consists of tools, resources, practices and techniques and formulated as PVs.
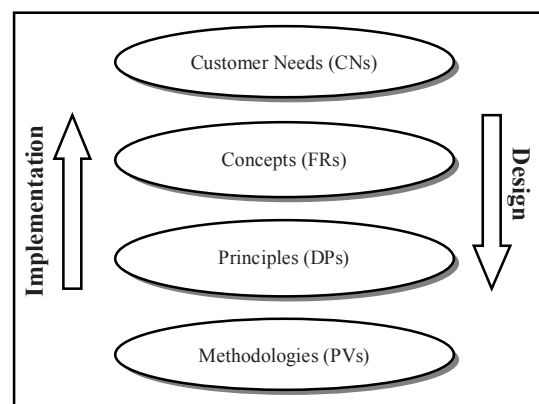

Fig. 2. Directions of the design and implementation of KMS based on AD theory (adapted from [17]).

The abstract notions embedded in concepts (FRs) and principles (DPs) hamper their straightforward applications. But, the use of methodologies (PVs) could be helped to convert the theory into practical action.

The main purpose of this paper is to present a roadmap for the design and implementation of a knowledge management system based on the axiomatic design principles. To do it, the following steps have been taken:

1) Review of the basic concepts and principles of knowledge management;
2) Review of the basic concepts and principles of axiomatic design theory;
3) Review of a variety of models, strategies, methodologies, and cycles of knowledge management for extraction of the common factors of knowledge management systems;
4) Review of the factors of success and failure related to knowledge management systems, to evaluate the factors affecting on knowledge management systems;
5) Review of the organizational strategy document and discussion with experts to extract specific criteria for design the appropriate knowledge management system for the understudy organization (TUSROC);
6) Presenting a knowledge management system based on axiomatic design principles.

4.1 Model presentation

Now, companies and organizations persistence is to improve their outputs and performance based on the knowledge. The ability of knowledge management systems has been proven as an efficient tool to achieve this goal. This notion reflected in Fig. 3. The applicability and successful implementation of this goal require a comprehensive view of all organizational factors. Hence, according to the results of extensive studies that have been conducted about the fundamental factors affecting on knowledge management systems, in this article six main factors affecting on a knowledge management system have been considered; that includes: 1. Organizational culture 2. Organizational structure 3. Human resources 4. Leadership and management 5. Information technology and 6. The external environment of the organization.

The main requirement of a knowledge management system (FR0) is 'Improving the organizational performance by knowledge based systems' which could be separated into the following six areas:

- Reduce resistance to change (FR1);
- Improve the organizational structure to adapt to change (FR2);
- Improve the human resources (FR3);
- Adoption of an excellence mentality (FR4);
- Develop the hardware and software basis (FR5);
- Use of external environment knowledge for the organization and vice versa (FR6).

To satisfy this requirement, six factors have been used as the related design parameters (DPs):

- Development and strengthening of organizational culture (DP1);

- Increasing the flexibility of the organizational structure (DP2);
- Expansion of the knowledge-based performance of personnel (DP3);
- Transformational leadership and management (DP4);
- Utilization of the IT techniques (DP5);
- Management of the external environment Knowledge (DP6).

The relationships of FRs and DPs of the first level of the model are shown in Fig. 3.

Alignment of the FRs with organizational strategy was the most notable limitation of our study. Therefore, to satisfy FRs, the DPs and PVs were chosen based on the elites suggestions through extensive literature reviews and discussions with experts of the 'TUSROC'. Also, this study assumes that the chosen DPs and PVs will satisfy the FRs appropriately. For example, to satisfy FR1, it is suggested that knowledge management culture should be adopted and expanded thorough organization. However, the knowledge management culture may not be fully accepted by everyone. It is necessary to remark that in the implementation phase some of the FRs may not be adequately met; in this case, it is essential to revise DPs and PVs.

4.1.1 Organizational culture

Careful analysis of the components of a knowledge management system, displayed in Fig. 3 shows that the organizational culture (DP1) is the Achilles heel of the knowledge management system, because it is associated with 'Improve the human resources' (FR3), 'Adoption of an excellence mentality' (FR4), and 'Use of external environment knowledge for the organization and vice versa' (FR6). It was predictable because when Robert Bachmann was asked to name three factors critical to knowledge management, said: "culture, culture, culture" [18]. The organizational culture is very important for the success of knowledge management system because any organizational change will be successful when the entire of the organization is committed to the processes of change [19]. Hence, the relationship of 'Development and strengthening of organizational culture' (DP1) with FR3 and FR4 is revealed. Also, each organization should commit itself to improving its stakeholders, thus DP1 will affect on FR6. For additional descriptions of these relationships refer to [20, 21].

For more explanation of the relationship between 'Reduce resistance to change' (FR1) and 'Development and strengthening of organizational culture' (DP1) and 'Creating the knowledge management culture' (PV1) we can state that "knowledge culture is a way of organizational life that enables and motivates people to create, share and utilize knowledge for the benefit and enduring success of the organization" [20]. So a knowledge management culture may be divided into three subcategories:

1) The knowledge sharing culture;
2) The knowledge acquisition culture;
3) The knowledge creating culture.

Decomposition of the components of FR1 is shown in Fig. 4.

Srivastava et al. [22] with an appropriate definition, introduce the knowledge sharing. They say "knowledge sharing is a critical team process that involves members interacting to share ideas, information, and suggestions relevant to the team's task at hand". Several studies have been done on factors influencing knowledge sharing in organizations and communities in order to facilitate the knowledge sharing. Gruber and Duxbury [23] identified several major factors in knowledge sharing culture, including openness, trust, availability, usage of different communication channels, and reward system in an organization. Another study shows the 'openness' and 'enjoy helping' have a strong relationship with knowledge sharing behavior [24]. Al-Alawi et al. [25] have investigated the role of certain factors in
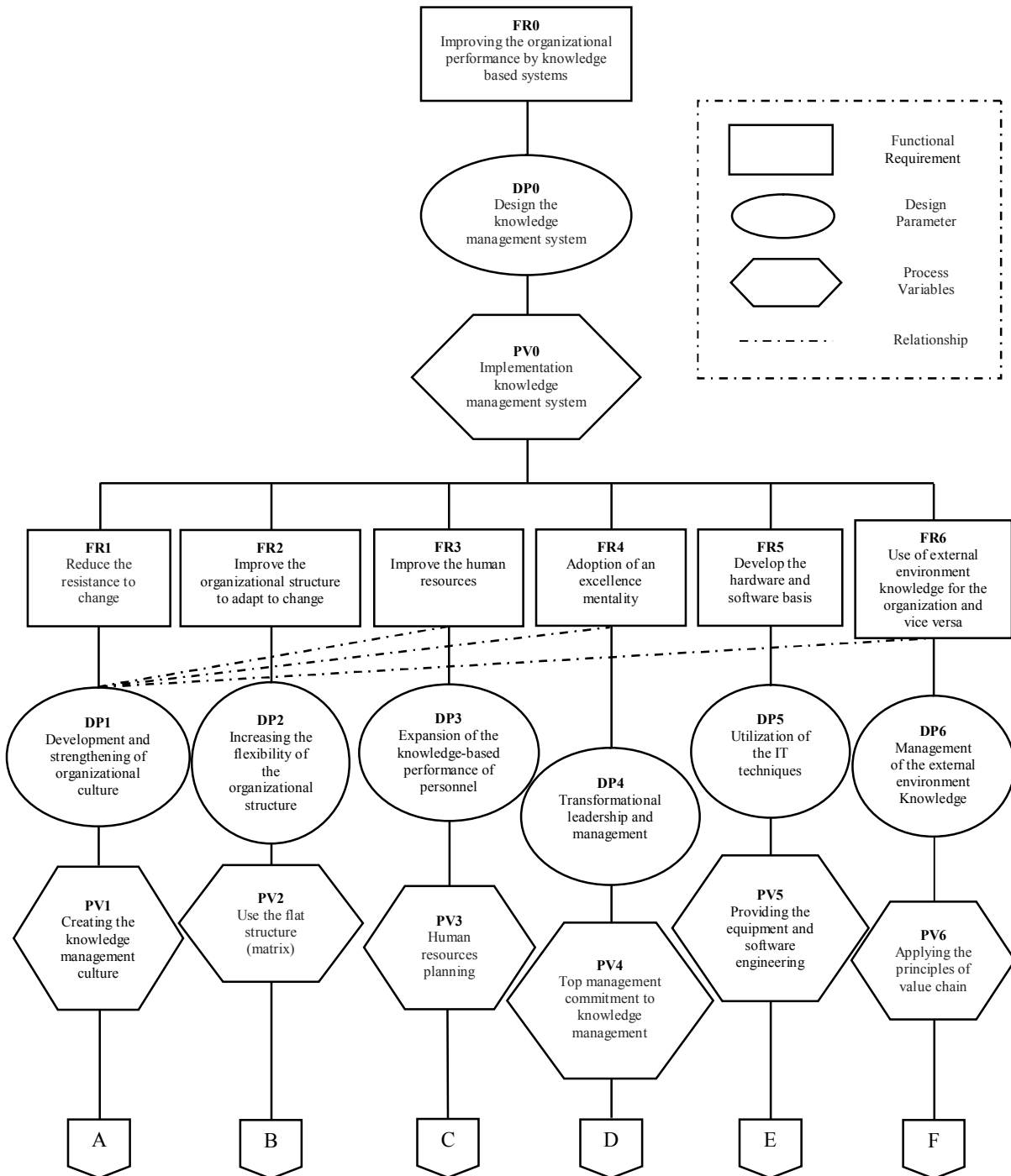

Fig. 3. First level of the knowledge management system decomposition.

organizational culture in the success of knowledge sharing using survey and a number of interviews with staff from various organizations in Bahrain from the public and private sectors. The research findings indicate that trust, communication, information systems, rewards and organization structure are positively related to knowledge sharing in organizations.

According to the most studies, 'openness' and 'trust' have the most impact on knowledge sharing in the organization, these issues are reflected in Fig. 5 by the relationship of the 'Building a culture of openness' (DP112) with 'Build the trust in the organization' (FR113) and 'Use of employee suggestions' (FR114) and as well as the impact of FR114 on 'Creating a culture of trust' (DP113). Since FR113 is an abstract and intangible issue, it is decomposed further (see Fig. 6 and 7).
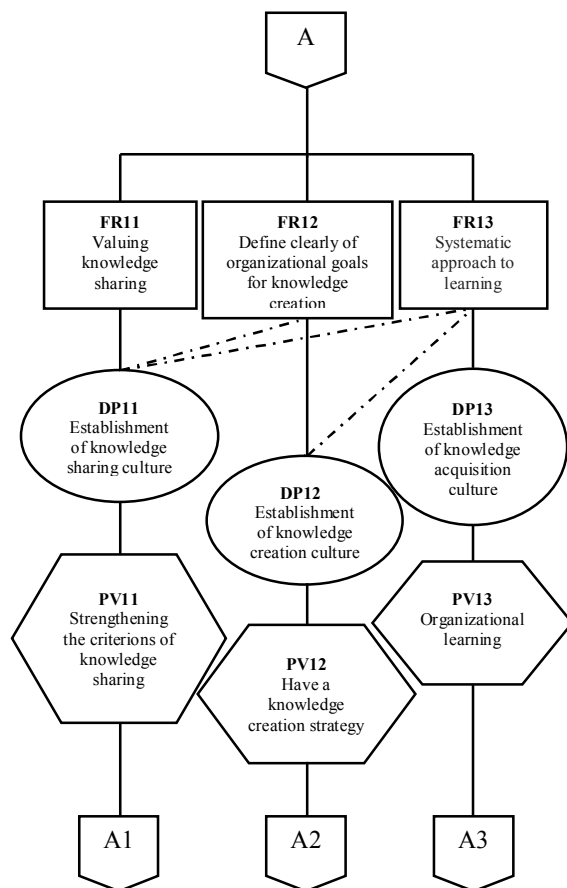

Fig. 4. Decomposition of FR1 'Reduce resistance to change'.

The knowledge creation is replacement or improvement of existing organizational knowledge through social relations and organizational cooperation [26]. By using new knowledge the organizations can improve their performance, capability and the appropriate use of existing resources. Hence the realization of concepts such as continuous improvement, organizational development, and sustainable competitive advantage depends on the continuation of the process of knowledge creation in the organization. Idea generation and opportunity exploration, enhance directly 1.

Stimulating and probing employees to generate ideas (intellectual stimulation), 2. Supporting open and transparent communication processes, 3. Creating avenues for knowledge sharing and diffusion, and 4. Assigning challenging tasks to employees [27]. The studies about creativity show that employees are willing to create unusual and useful ideas. Experiences have shown that the supportive and informative assessment of employees may improve the internal motivation, which is beneficial for creativity. Organizations may be successful in exploiting knowledge in the short-term, however, in the long term, the learning and knowledge creation occurs less. Knowledge creation skills are very important and the improvement of knowledge is required to develop new processes. Success indicators of knowledge creation are the assessment of the validity of knowledge, acceptance of knowledge and preparation for using it in the organization. According to what was said, the decomposition and the relationship between components of 'Define clearly of organizational goals for knowledge creation' (FR12) are shown in Fig. 8.

Another component of 'Reduce resistance to change' (FR1) is 'Systematic approach to learning' (FR13) which 'Establishment of knowledge acquisition culture' (DP13) and 'Organizational learning' (PV13) provide the tools, resources, and procedures to satisfy it. It should be noted that by improving communication and interaction among employees and relying on different knowledge structures, the organizational capacity increases to acquire new knowledge and innovating idea to achieve the objectives. Peter Senge [28] believes that "The only sustainable competitive advantage is an organization's ability to learn faster than the competitors". Organizational learning occurs when the information is collected and analyzed for the creation and development of new facts, then with communication, teaching, dialogue, and interaction of personnel is spread to all levels of the organization. The process variables that have been intended to acquire knowledge includes:

- User ID definition for access to organizational documents (PV131);
- Team-based learning (PV132);
- Provision of requirements and research grant (PV133);
- Analysis of process flow (PV134);
- Teamwork workshops (PV135);
- Database creation (PV136).

Figure 9 shows the relationship of components of FR13.

4.1.2 Organizational structure

Figure 10 presents the decomposition of 'Improve the organizational structure to adapt to change' (FR2). Since the organizational structure is the framework of organizational processes and activities of employees, it is the driving force behind organizational changes. In other words, without a suitable organizational structure, having the best employees and enormous investments on knowledge management implementation will not be useful. Organizational structure is generally described according to degree of centralization, formalization,

complexity [29] .Organizational structure can enhance or impede the success of knowledge management system. The centralization and formalization are critical factors in organizational structure that impede the creation, transmission, storage and application of knowledge directly. Low centralization and formality improves organizational effectiveness by increasing the level of organizational interaction, employee motivation, and flexibility [30]. The existence of formality and centralization decreases the amount of creative solutions, while the autonomy in the organization causes self-motivation, empiricism, and freedom of expression [31].
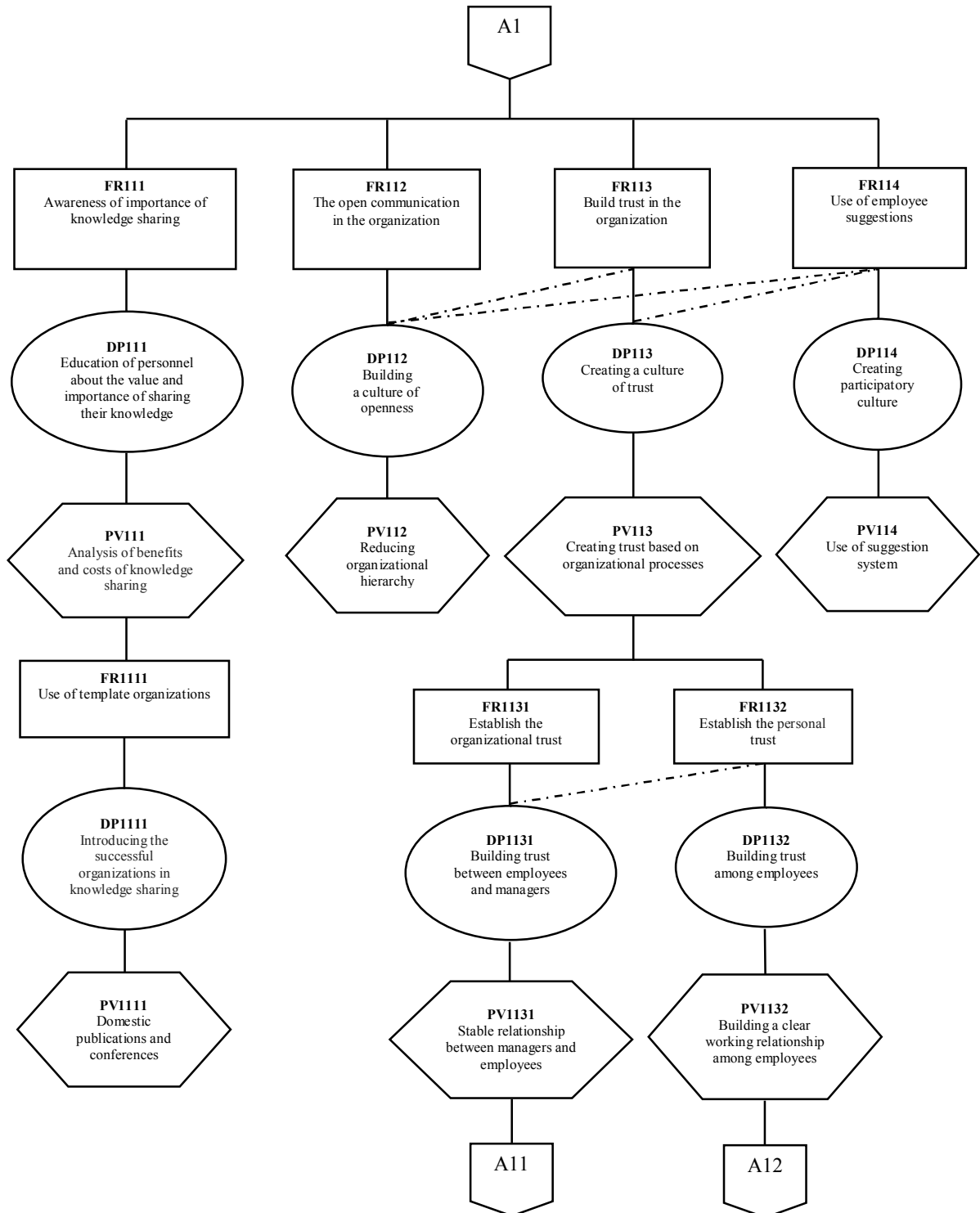
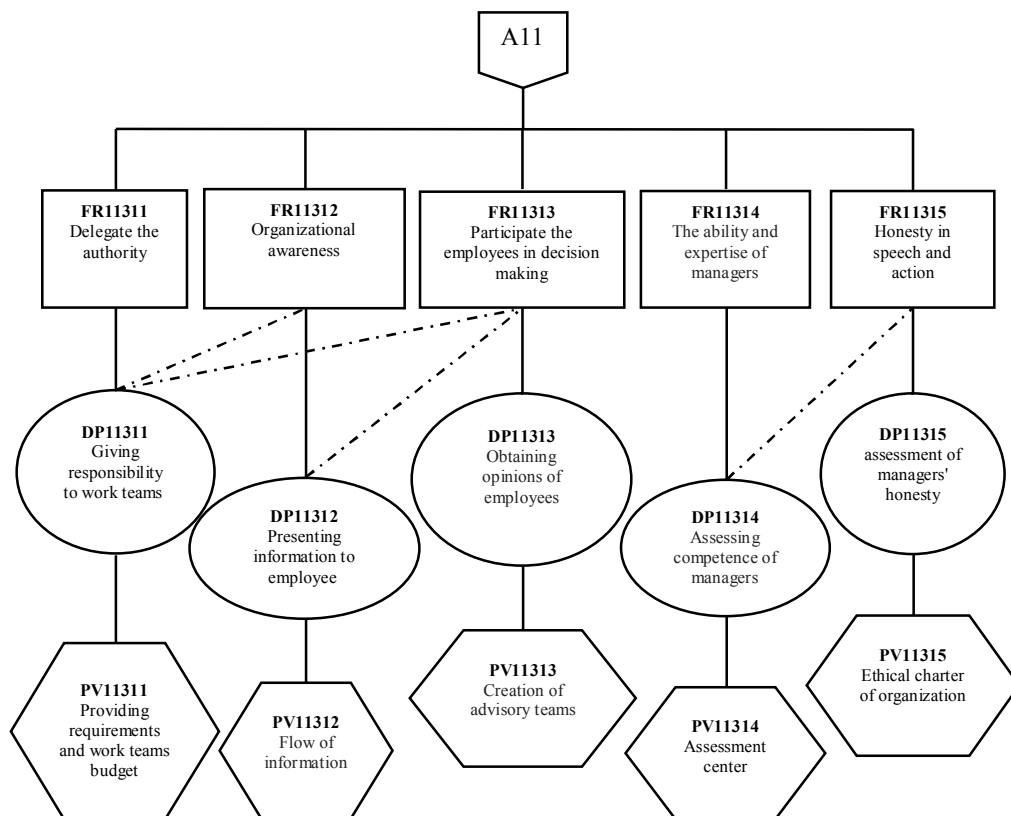**Fig. 5.** Decomposition of FR11 'Valuing knowledge sharing'.

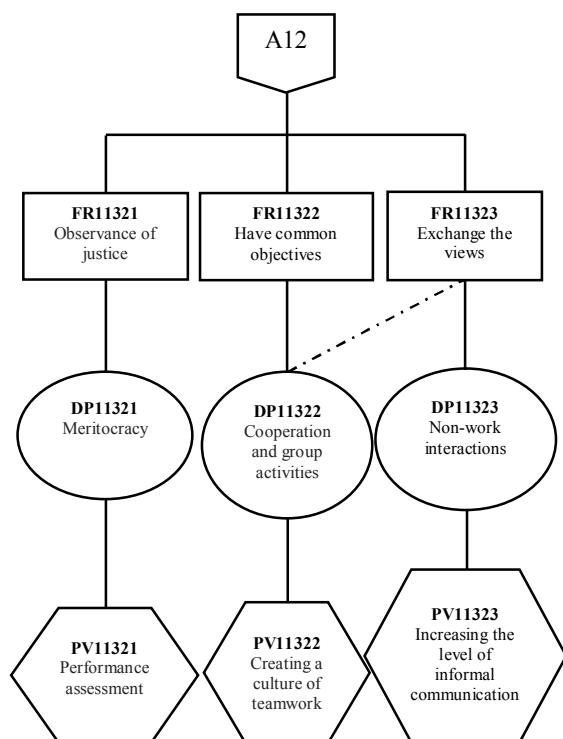**Fig. 6.** Decomposition of FR1131 'Establish the organizational trust'.

Fig. 7. Decomposition of FR1132 'Establish the personal trust'.

4.1.3 Human resources

The employees of an organization are the main source of competitive advantage because the human resources of any organization are not easily copied by competitors. Competitors can easily produce the same products, can use the same technology and can access to same capital markets. While these competitors cannot easily provide similar conditions to attract and retain human talent, these conditions are formed during a long period of time. Also, copy of social relations derived from human resources is difficult. Therefore, the capabilities of human resources has become to be one of the most fundamental sources of sustainable competitive advantage [32].

The human resources issues such as recruitment and selection, training, performance management, pay and reward system as well as creating a culture of learning are essential for knowledge management [33]. Improvement of human resources is a set of methods and measures that the organization and managers are using to improve efficiency, productivity, motivation, improvement of quality, performance assessment, job satisfaction, dynamism, and creativity of employees according to the goals of the organization. Yang Fong et al. [34] in their study concluded that recruitment and selection, teamwork, training and development, and performance appraisal, shows a positive relationship with knowledge sharing. The relationship of these items is shown in Fig. 11.
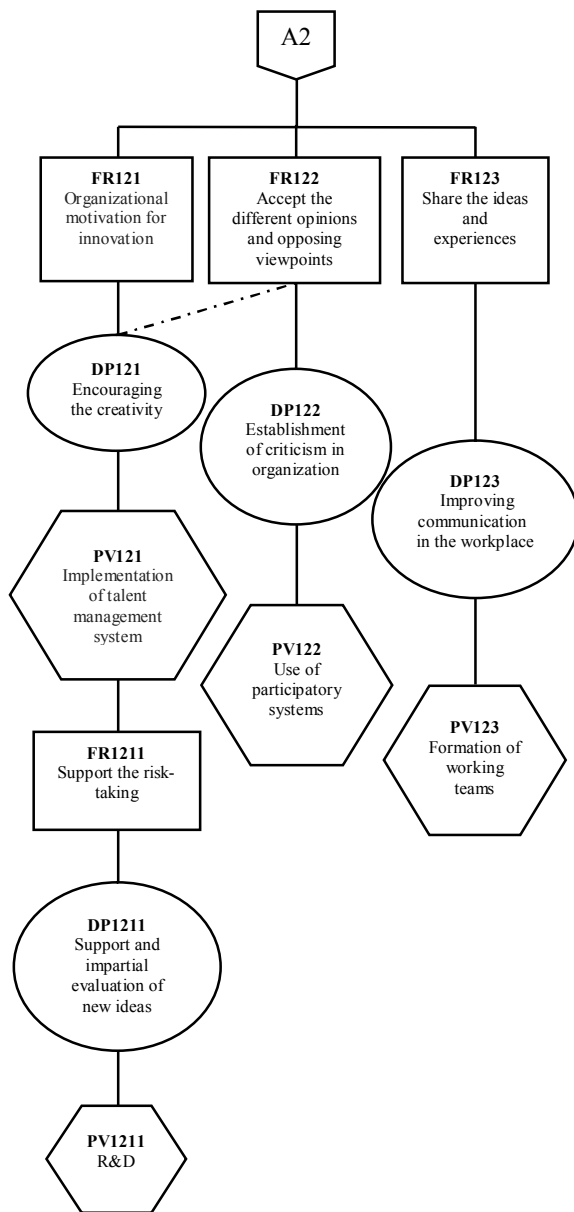
Fig. 8. Decomposition of FR12 'Define clearly of organizational goals for knowledge creation'.

4.1.4 Management and leadership

Another top-level FRs of the model is 'Adoption of an excellence mentality' (FR4), that is necessary for successful implementation of knowledge management system. 'Transformational leadership and management' (DP4) is considered to satisfy FR4. Successful implementation of knowledge management systems requires the commitment of top level of management to knowledge management efforts. In other words, a paradigm shift in the philosophy of top management is needed to be focused on defining the vision, goals, roles and responsibilities of top management. Many researchers believe that the attributes of positive leadership in different levels of management are one of the most important requirements to create a knowledge culture. The relationship of the DP1 with FR4 shows this issue. The mentioned attributes include empowering subordinates, allocation of resources, openness towards change and experimentation, developing trust, tolerance to mistakes, and building long-term perspective of the organizational goals among employees [20]. Senior managers must have the following characteristics:

- The ability to coordinate the various units involved in the implementation of knowledge management processes (FR41);
- Realistic prediction of the results of knowledge management activities (FR42);
- Persuading the employees to innovate (FR43);
- Constant communication with employees and considering their ideas (FR44).

Elenkov [35] believes that "Intellectual stimulation has been viewed as a leadership behavior that challenges followers to re-examine some of their assumptions about their work and rethink how it can be performed". The attention to all employees is one of the new theories of leadership. This means that the leader observes the everyone's behaviors and is aware of their activities. The leaders assess the individual situation of employees and spend the time to guide, train, and recognize their abilities and creativities. Therefore, they can plan to develop employees capabilities. These factors have a positive effect on learning, development, satisfaction, effort and commitment of employees. Decomposition of FR4 is presented in Fig. 12.

4.1.5 Information technology

Organizations use IT to control and manage their knowledge assets. In other words, organizations use information technology to provide the possibility to achieve a competitive advantage through knowledge assets. In fact, IT is a phenomenon that has arisen from widespread usage of computer systems in organizations, society, and its profound transformation. Providing information systems such as the internet, intranet, extranet, groupware, etc. for storage, transfer, and exchange of knowledge, as well as providing the facilities for easy access to the hardware and software for sharing information are necessary. The employees, by aids of information systems, will help organizations to gain information technology in knowledge management system effectively. Knowledge management and information technology are strongly linked together to promote structured knowledge in organizations. The important role of information technology is supporting organizational communications, collaboration, empowerment of the cooperative learning and search of knowledge. Requirements for an effective IT system include information quality, flexible IT infrastructure, access to hardware, access to software, network, and information systems [36].The tools that can be used to meet the goals of information technology in the knowledge management system include:
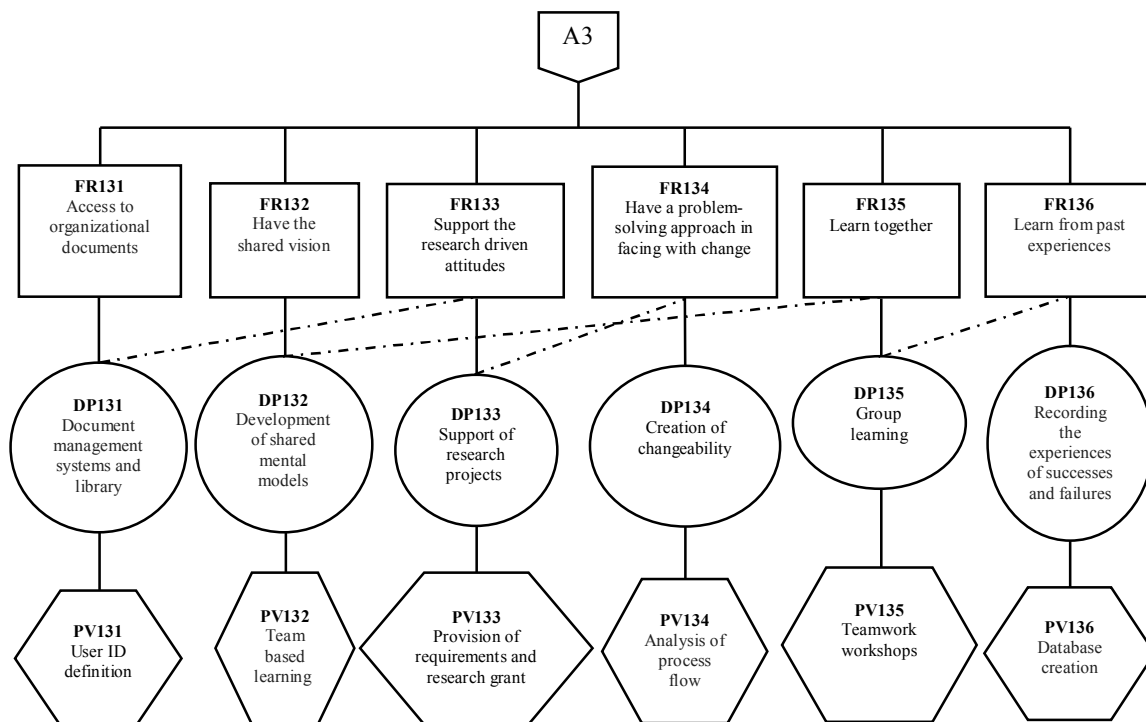
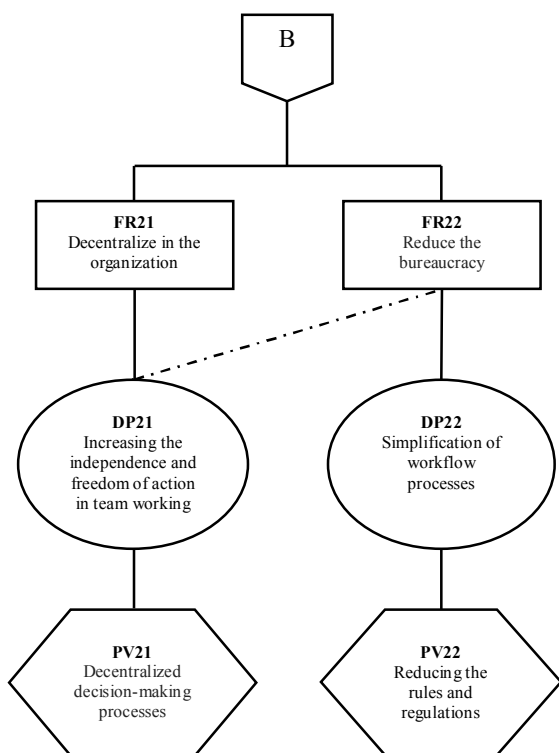**Fig. 9.** Decomposition of FR13 'Systematic approach to learning'.

Fig. 10. Decomposition of FR2 'Improve the organizational structure to adapt to change'.

- The comprehensive software of knowledge management system (DP51): is a web-based information system that can be installed on a local and global computer network and has the capability of acquiring, creating, storing, sharing and retrieval of knowledge that created by the employees during work processes.

- Network-based tools (DP52): information networks are the suitable environment for sharing dynamic information that the hypertext structure of it facilitates the review of information and access to classified information.

- Decision support system (DP53): a decision support system (DSS) is a computer-based information system that supports business or organizational decision-making activities, typically resulting in ranking, sorting, or choosing from among alternatives. DSSs serve the management, operations, and planning levels of an organization and help people make decisions about problems that may be rapidly changing and not easily specified in advance problems. DSSs include knowledge-based systems. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from a combination of raw data, documents, and personal knowledge, or business models to identify and solve problems and make decisions.

- Knowledge-based systems (DP54): includes a knowledge base in the limited field that provides an inference mechanism, the changing of information and entering new data.

The relationship between FRs, DPs, PVs in the field of information technology is shown in Fig. 13.
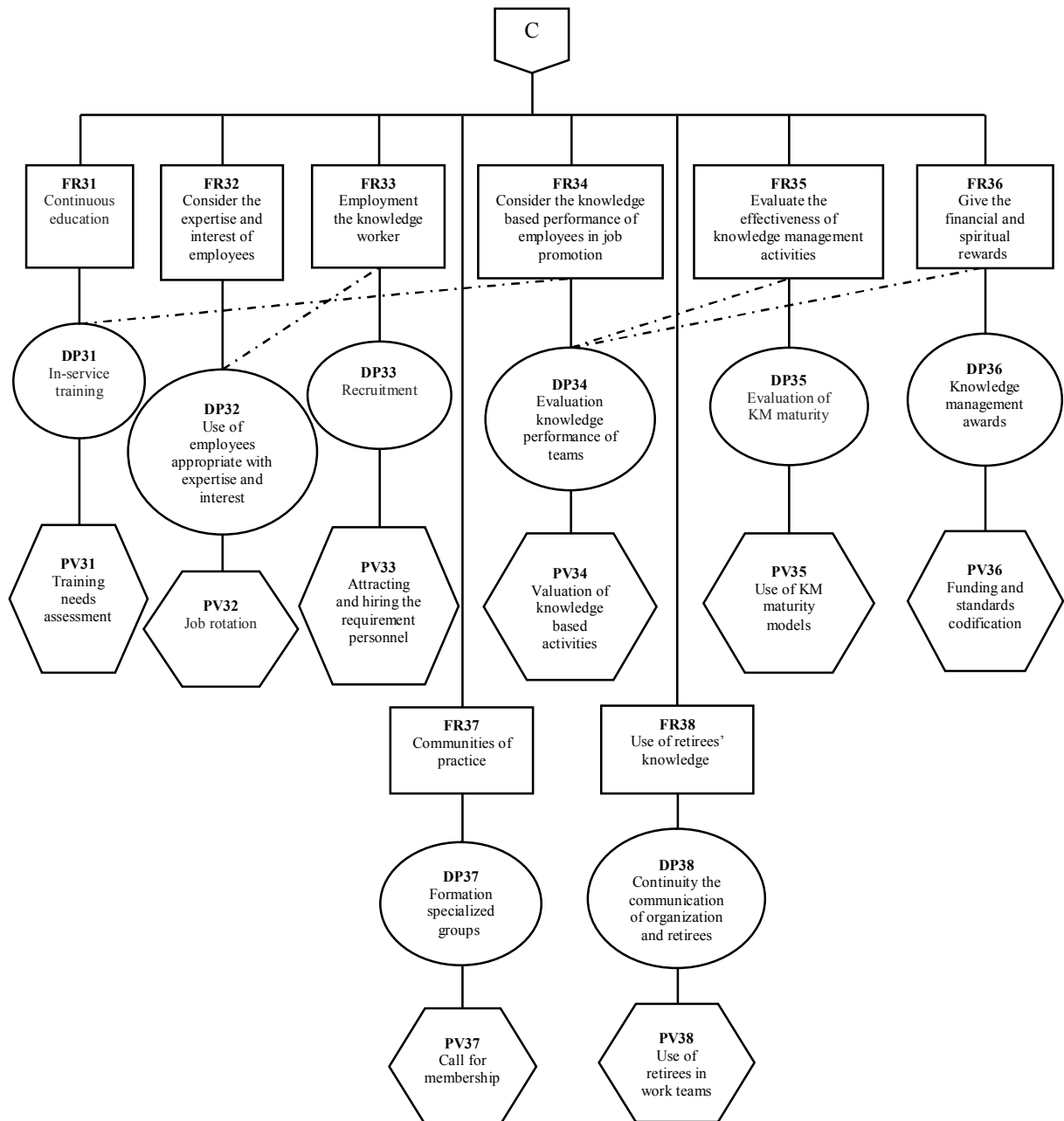
Fig. 11. Decomposition of FR3 'Improve the human resources'.

4.1.6 The external environment of organization

Since the business activities of organizations have been transferred to the supply chain level, the challenge of managers is keeping the competitive advantage by creating the stronger relationships with employees, customers, suppliers, upstream and downstream partners.

Fugate et al. [37] for acquiring knowledge in logistics systems, introduce the several factors which includes: polling customers, visiting customers' sites for better understanding of their needs, being involved in sales activities, being involved in helping to resolve customer problems, accompanying employees who deliver logistic services to observe how things work, visiting facilities of leading companies, visiting suppliers to learn more about various aspects of their business, attending events that allow networking, such as business colleges, research bodies, industry associations, trade shows, reading reports from the government and regulatory bodies. Liao & Wu [38] introduced the other indicators, including: processes for acquiring knowledge about customers and suppliers, use feedback from projects to improve subsequent projects, exchanging knowledge with business partners, acquiring knowledge about new product/services within their industry, acquiring knowledge about competitors, benchmarking performance, and formation of teams devoted to identifying best practice.
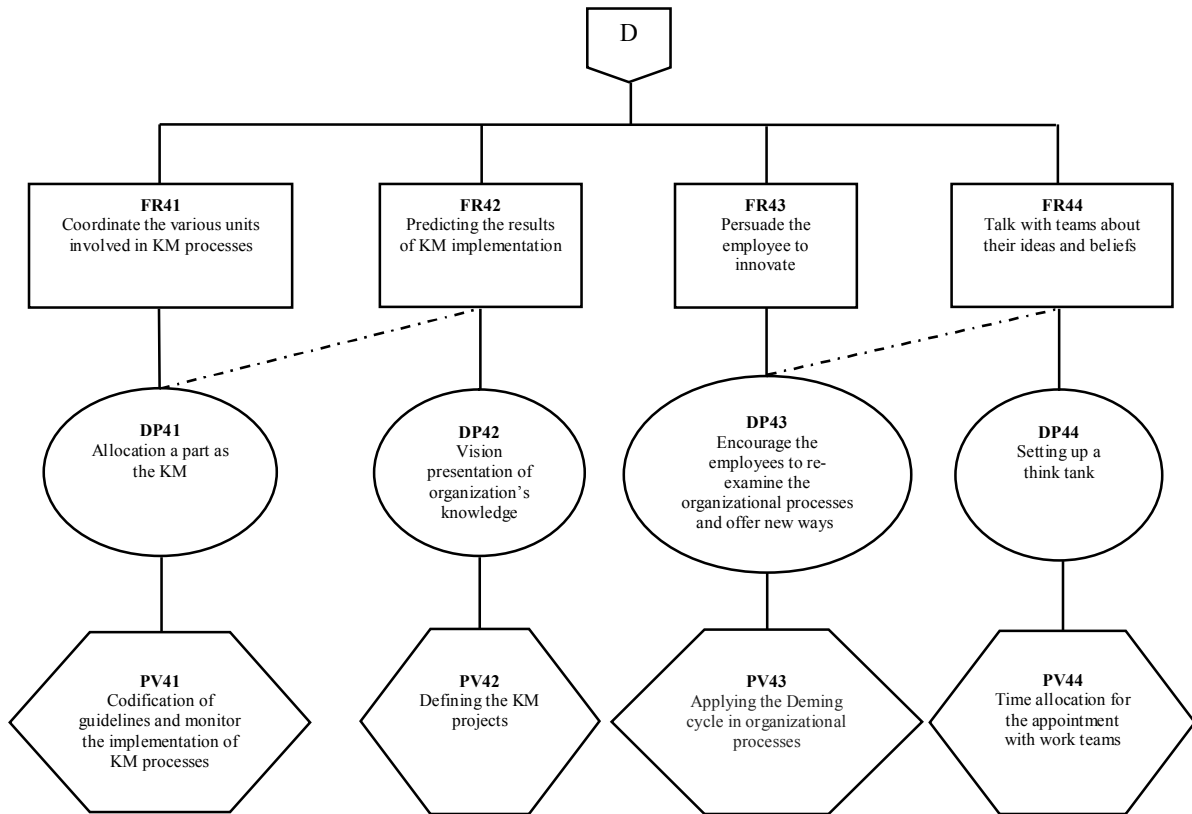
Fig. 12. Decomposition of FR4 'Adoption of an excellence mentality'.
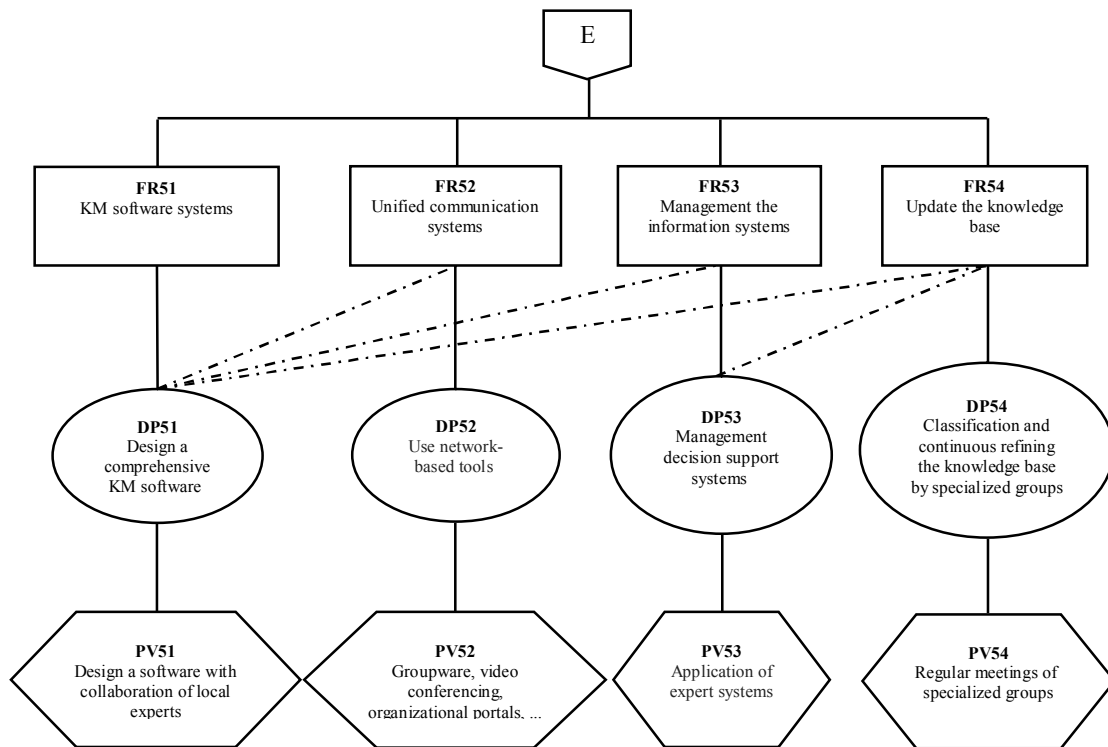

Fig. 13. Decomposition of FR5 'Develop the hardware and software basis'.

Fawcett et al. [39] have divided the process of knowledge sharing among supply chain into two key areas that are the communications and trends. They have introduced the indicators for the communications sector, such as: integration of information systems, high integrity of informational applications, systems related to customers, information systems for communications with chain members. Trends sector indicators include: regular communications with high frequency among members of the chain, sharing the information among members of the chain, the use of cross-functional groups, technical information sharing with suppliers and customers, senior level managerial interaction among supply chain members and use of supply chain teams with members from multiple firms. Hence, it seems that cloud-based solutions have the capability to provide KM services for enhancing the competitive advantage, share price, market share, productivity, response time, profitability, and decision making of the organization. Therefore, cloud-based solutions are the new tools that assist greatly in knowledge management efforts of an organization. The relationships of parameters, tools, and processes that has been considered for the management of supplier's knowledge is shown in the Fig. 15.

Nowadays, with the growth of customer's role in the competition, the information and knowledge of them have become more important in knowledge acquiring from the external environment of the organization that could be an important source for innovation. Today's the customers have a valuable information about companies, products, services, markets, and competitors that are stored in the minds of customers implicitly and can be affected on innovation directly and on the efficiency of innovation indirectly. So that many organizations are looking for managing the customer knowledge along with knowledge of the organization to acquire the knowledge and ideas of customers [40]. Related knowledge of customers has different shapes and are derived from three channels. These channels are 1. The analysis of customer data, 2. Engagement with the customer, 3. Observation of the customer behavior [41]. Fig. 16 shows how these factors are applied.

Another important component of the knowledge management of the external environment of an organization is 'Use of competitor's knowledge' (FR63). Fig. 17 presents the decomposition of it. The knowledge of competitors is consists of the key capabilities of the competitors. In other words, competitor information contains all of the data about competitor's outputs [42]. By using this information, managers are able to make-decision with a complete notion of the current situation and future of the competition. The experts of the competitive intelligence community, state that the competitive intelligence is an ethical and systematic program for the collection, analysis, and management of the external organization's information that effecting on the programs of the organization. In other words, competitive intelligence is the improvement process of competitive ability in the market, through attention to the competitors and the competitive environment, especially for the collection and analysis of the information of capabilities,

weaknesses, and intentions of business competitors by using the databases and open resources, ethically and legally. García-Murillo and Annabi [43] consider the competitor knowledge as a part of the organizational knowledge that components of it are: competitors as a partner, the knowledge of competitor's customer, the knowledge of competitor's market, the knowledge of competitor's suppliers and the knowledge of competitor's products/services. Some of the usefulnesses of competitive intelligence are:

- Increasing the confidence level of strategic decisions based on the competitive intelligence;
- Increasing market knowledge;
- Improvement of cross-functional communications in the organization;
- To help predict the market trends and fluctuations;
- Improvement of competitor's strategy prediction;
- Discovering the new customers;
- Learning lessons from success and failure of others;
- Facilitating to enter into new business;
- Increasing the productivity;
- Increasing the ability to adapt to the environmental changes.

5 Discussion

If we believe that the knowledge management is one of the requirements and competitive advantages of the organizations, we should use it carefully. The first and fundamental step to carry out a knowledge management system successfully is a right designing for it. The right design is a design that considers the needs of organizations and provides the tools, techniques, suitable and optimized processes to meet them. The main purpose of this study is the usage of the axiomatic design theory capability to design a knowledge management system for 'TUSROC' to providing suitable tools and process to satisfy the requirements of its knowledge management system that is adapting to change and moving towards innovation.

In knowledge management system based on axiomatic design, design starts with a defined framework and proceeds systematically. The creative actions are used by considering the appropriate DPs and PVs. In this work general requirements of knowledge management systems considered in the general framework of AD model, however, the specific needs, capabilities, and resources of 'TUSROC' that extracted from the strategic document and discussion with experts of 'TUSROC' have been considered as FRs, DPs, and PVs in different levels of the model. The important advantage of an AD-based model of knowledge management system is the formation of plausible relationships among different levels of design, conceptual level to practical levels. The procedure that we used in this model can be used to design a knowledge management system in any other organization.
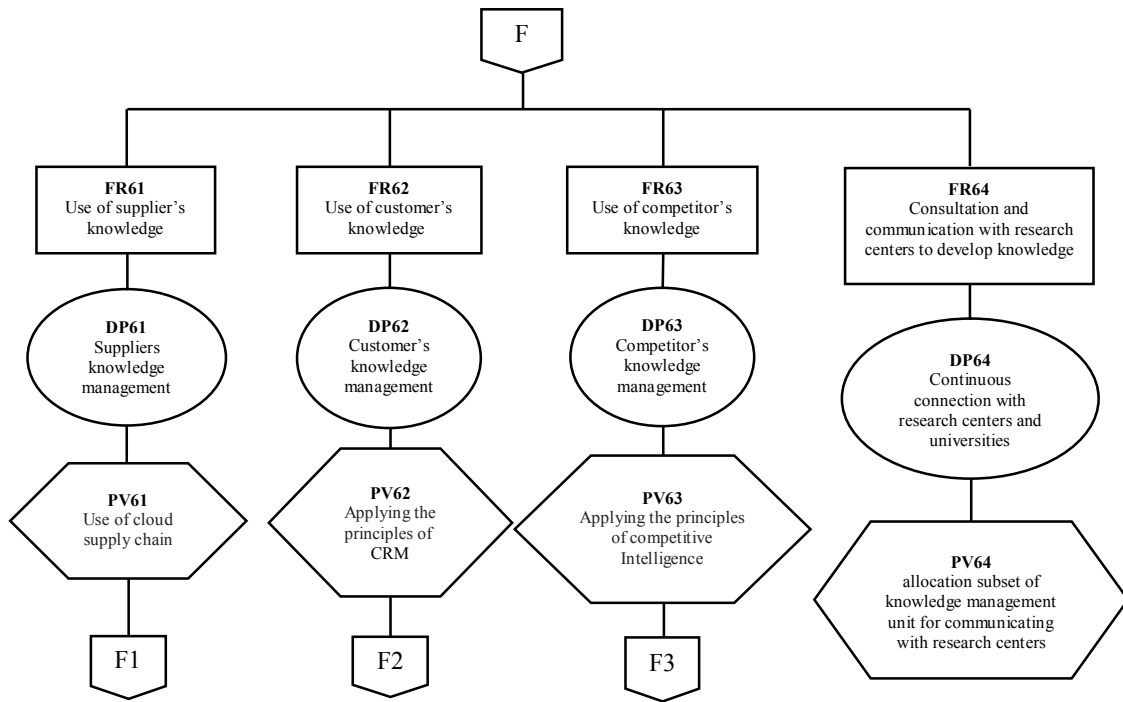
Fig. 14. Decomposition of FR6 'Use of external environment knowledge for the organization and vice versa'.
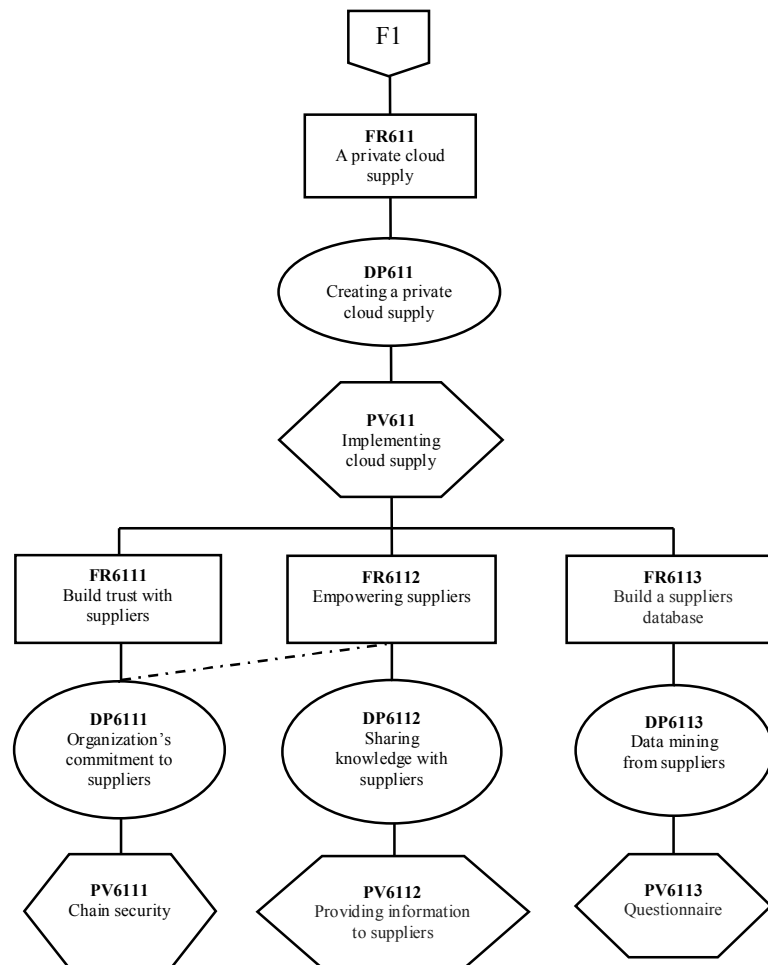
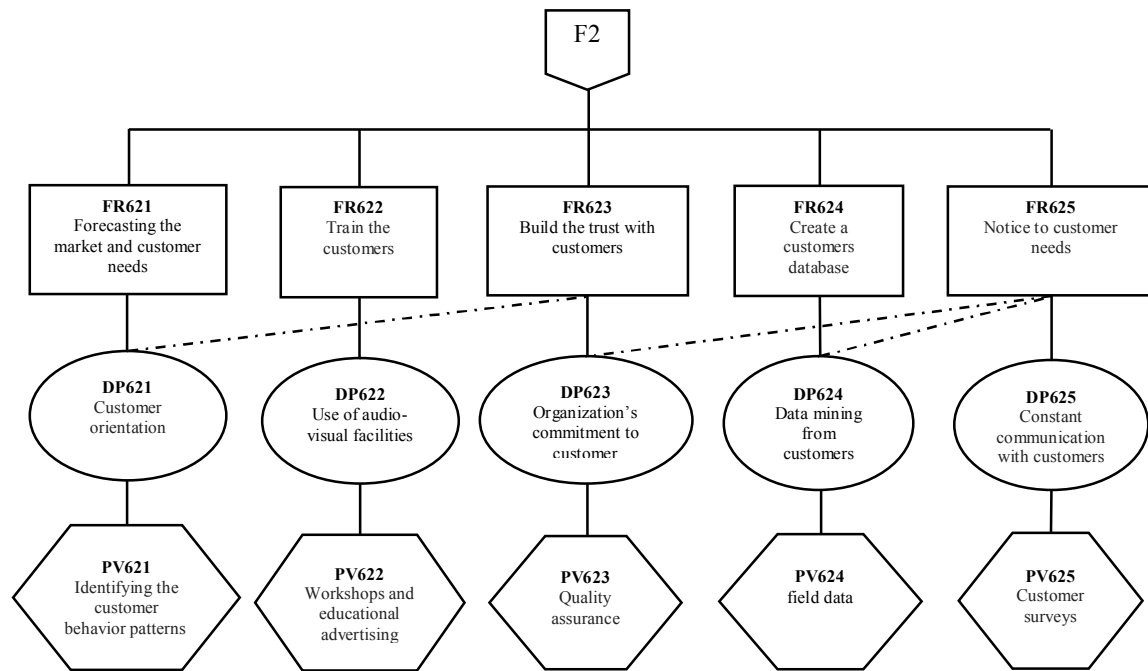**Fig. 15.** Decomposition of FR61 'Use of supplier's knowledge'.

Fig. 16. Decomposition of FR62 'Use of customer's knowledge'.
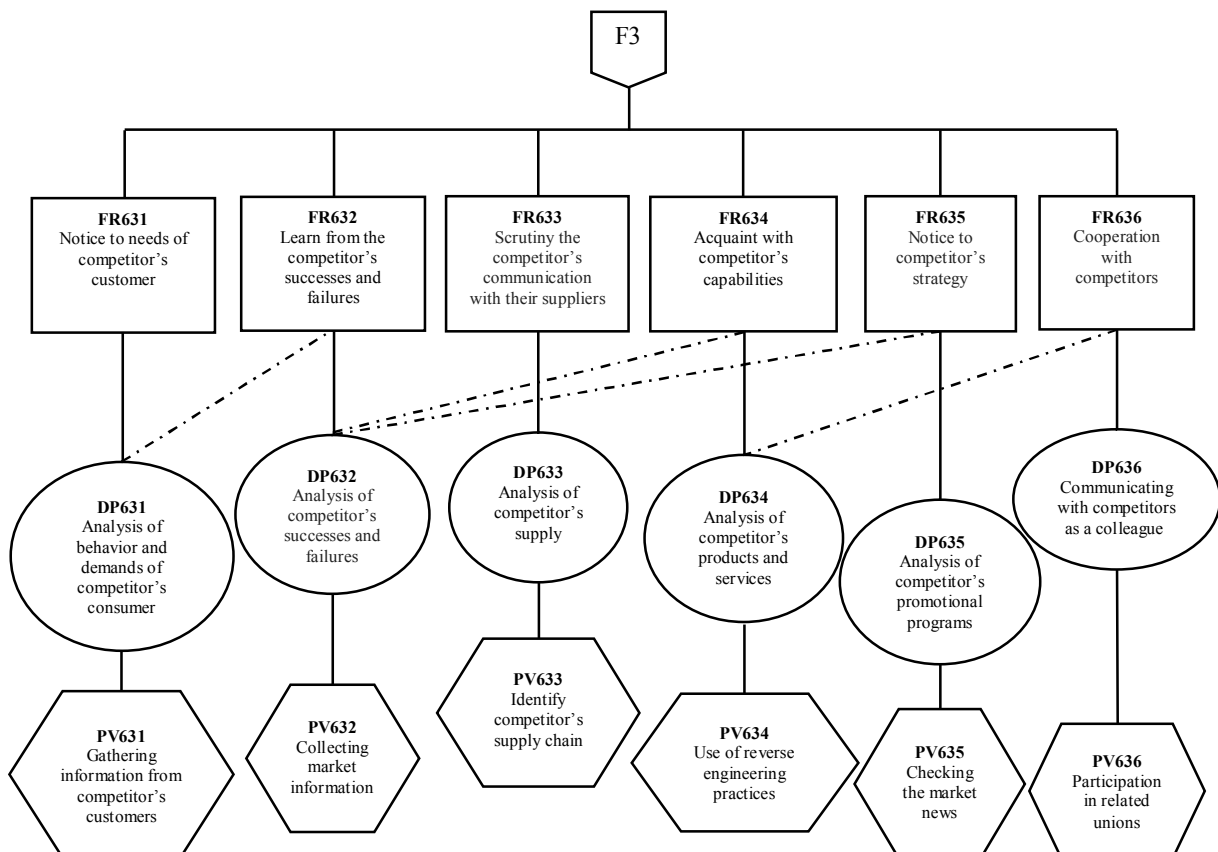

Fig. 17. Decomposition of FR63 'Use of competitor's knowledge'.

6 Conclusion

The AD based knowledge management system design for 'TUSROC' is discussed in this paper. We proposed an axiomatic model that provides a scientific base for concepts, principles, and methodologies of a knowledge management system and thereby alleviating many existing implementation shortcomings such as: lack of a scientific foundation for knowledge management and its associated transformation process, lack of precisely identified needs and reasons for change, resistance to change etc. The clear and tangible results of this work are:

1) Presenting a roadmap for design and implementation of a knowledge management system in 'TUSROC'. This model implemented in 'TUSROC' and so far the results have been very promising.
2) Learning: The developed AD model for KM can easily be transferred to novices to acquire the concepts and procedure of knowledge management system.
3) Using AD principles and relying on axioms of the subject, reduced the trial and error and the risk of failure.
4) The formation of plausible relationships among different levels of the model helps to implement issues easily.
5) By separating the functional requirements, parameters, and variables, it is possible to predict the results of activities. This helps orientation of future decision-making, control of activities, and allocation of resources where knowledge management system is implemented.
6) Providing a common and clear procedure in the framework of the design, it will help to communicate between different sectors of the system effectively.

For future research, it is suggested that the proposed model in this study to be optimized by applying the second axiom of the AD theory to consider several DP for each FR and several PV for each DP.

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