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ScienceDirect
Omega 36 (2008) 633–652
omega
The International Journal of Management Science
www.elsevier.com/locate/omega

A methodology for the design of office cells using axiomatic design principles[☆]

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Received 16 September 2003; accepted 27 October 2005
Available online 3 March 2006

Abstract

Office operations play a significant role in organizational performance; however, their contribution to competitive advantage has not adequately been addressed in the literature. In this study, we develop a methodology for designing an efficient office operation using axiomatic design principles. Axiomatic design allows the use of well-understood patterns of all necessary information when formalizing design objectives. We use these principles to design office cells, and claim that this methodology will improve office operations and contribute to business competitiveness through a reduction in customer lead time. We provide a detailed description of the methodology applied to office cell design, which consists of cell formation and operation, as well as the results of a real-world implementation. Our findings indicate that the methodology works well in improving office operations because it eliminates many non-value-added activities.

Keywords: Office cells design; Teams; Axiomatic design

1. Introduction

One of the reasons that firms take a long time to respond to customer inquires can be attributed to the lead time related to office operations. In manufacturing firms, office lead time, i.e., the time between receiving an order and releasing it to the shop floor, contributes to more than 50 percent of the total customer lead time [1]. In service firms, studies show that approximately 98 percent of customer lead time consists of non-value-added activities [2,3]. Therefore, if such activities were eliminated, customer lead time could be reduced, considerably.

One method of addressing this problem would be to develop cellular office layouts [1,4] which we refer to as team-based office cells or office cells, for short, throughout this paper. Single-operator office cells are not considered in this paper. Office cells can improve performance by facilitating better communication and control similar to that found in manufacturing cells. In other words, office cells provide a good foundation for teamwork, and provide better communication and control because team members are located in close proximity to each other.

Swank [5] describes how to implement lean production principles at the Pilot Financial Service Company and explains the benefits in detail, specifically using a

☆ This manuscript was processed by Area Editor B. Lev.

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doi:10.1016/j.omega.2005.10.007

model office cell. Although lean production principles are usually applied as a manufacturing concept, this study shows that lean tools can be successfully adapted for service industries. Tapping and Shuker [6] present the practitioners how to apply the value stream management (VSM) process to administrative work. In this work, the application of lean management principles to a value stream is defined as VSM and the explanations of the eight steps of VSM for a complete system of lean office are given.

Hyer and Wemmerlöv [7] focus on the basics of office cells—what they are, what benefits they produce, and how you create them. An eight step process for designing office cells is also presented within the context of this study. In their other study, Hyer and Wemmerlöv [4] offer a methodology to perform the design steps of office cells effectively. In addition, the process improvement tips and 14 principles needed to create and operate office cells are described in detail. Suri [1] develops quick response office cell design (Q-ROC) approach which is mainly focused on reducing lead time. The author explains the principles and tools that can assist with the initial analysis, design and eventual implementation of a Q-ROC.

Axiomatic design (AD) is a tool that is particularly suited to the design problem because it addresses how to handle cross-functional issues in designing office cells. Many AD applications in designing products, systems, organizations, and software have appeared in the literature in the last decade. AD theory and principles were introduced for the first time by Suh [8]. Kim et al. [9] apply AD principles to software design. AD principles are also used in quality system design [10] and general system design [11,12]. Suh et al. [13] provide a manufacturing system design methodology using AD principles. Then this methodology is improved by Cochran et al. [14]. Kulak et al. [15] develop a road map for the design of cellular manufacturing systems using the independence axiom. Fuzzy information axiom for multi attribute decision making module is developed and applied to the selection of material handling equipments [16] and the selection of punching machines in a manufacturing system [17]. In addition, AD principles are applied in designing flexible manufacturing systems [18]. Other applications of AD include process and product development [19]. These studies have convincingly shown the applicability and benefits of AD in solving industrial problems.

This study develops a road map using the independence axiom in order to design office cells effectively. The road map provides a decomposition of broad design objectives into smaller supporting objectives that are then linked to specific design parameters for framing office cells. In other words, this methodology creates the decomposition process that enables a clear formulation of design objectives. The remainder of this paper is organized as follows. The next section provides a brief definition of office cells and their benefits. In Section 3, the basic concept of axiomatic design principles is introduced. A methodology applying cellular thinking to design and run office cells is presented in Section 4. The office cells created in the study are implemented in a loyalty-marketing group of companies and given in Section 5. The final section contains the future research.

2. Office cells and their benefits

A cell is a small organizational unit within a production system that is designed to exploit similarities in processing information, making products, and serving customers [4]. A small group of people and equipment are closely located within a cell to perform interrelated tasks of a product, a service or a project [20]. Such a structure can simplify a complex production system by dividing it into effective and controllable smaller units. Since the production system consists of these smaller units or cells, the properties of the cells, such as ability and efficiency, are reflected to the whole system without loss.

As a result, cells ensure decentralization. A classical manufacturing system (i.e., a job shop) is a functionally organized system. In the machine shop area of such a manufacturing system, milling machines are grouped separately from lathes. The production system, which services this job shop, is also organized functionally [21]. All personnel involved in process planning, production planning, purchasing, quality, and budgeting are located in different areas. Walls usually separate these people in their functional areas from all other areas. Breakdowns in communication links are common. Therefore, this centralized organization does not fit well with teams and employee-involvement approaches. It often inhibits total-quality approaches [22]. However, it is generally preferred because of its ease of design. It concentrates expertise in the same area and provides, theoretically, better personnel and equipment utilization.

Building manufacturing cells within a manufacturing system alone will not be sufficient to integrate the manufacturing system into a production system. In such an organizational structure, manufacturing lead time can be shortened, but many non-value-added activities may still exist in the system, which may not yield sufficient reduction in overall customer lead time. As mentioned before, office lead time is more than half the total lead time in a manufacturing company [1]. Therefore, a decentralized organizational structure for office operations, which plays a substantial role in the performance of a system, should be built to shorten total lead time. For this reason, people from different production areas leave their functional structure and become a team, thus creating the office cell for a product, a service or a project family.

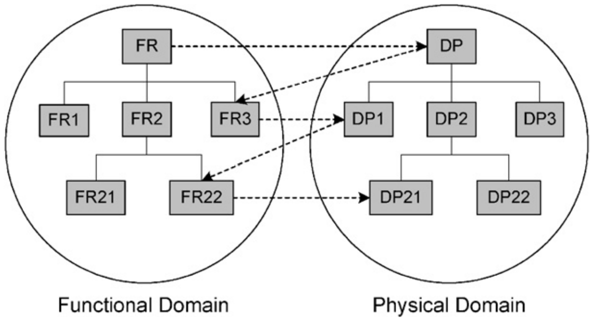

Fig. 1. Zigzagging to decompose FRs and DPs.

3. Principles of axiomatic design

Design is the interplay between *what* we want to achieve and *how* we want to achieve it [19]. The precise description of "what we want to achieve" is a difficult task for designers. Many designers often begin working on design solutions before they have clearly defined goals. They also try to measure success by comparing their design with design goals that may not be established through customers' needs. Therefore, they spend a great deal of time on improving and iterating the design. In order to generate an efficient design, the designer must begin the design process by stating the goals in terms of "what we want to achieve" in light of customer's needs. The AD approach provides a new search process using these iterations between "what" and "how."

The most important concept in axiomatic design is the existence of design axioms. The first design axiom is known as the independence axiom (IA), and the second axiom is known as the information axiom. They are defined as follows [8]:

Axiom 1—The independence axiom: *Maintain the independence of functional requirements*.

Axiom 2—The information axiom: *Minimize the information content.*

The IA states that the independence of functional requirements (FRs) must always be maintained, where FRs are defined as the minimum set of independent requirements that characterizes the design goals. Design parameters (DPs), which are the key variables, are chosen to satisfy the specified FRs throughout the design process. The information axiom states that the design with the smallest information content among those satisfying the first axiom is the best design [19]. The second axiom is not considered in this paper.

Zigzagging to decompose FRs and DPs and to create their hierarchies is an important part of axiomatic design. In order to zigzag between domains, designer starts out in the "what" domain and goes to the "how" domain. From an FR in the functional domain, we go to the physical domain to conceptualize a design and determine its corresponding DP at the highest level. Then we come back to functional domain to create FR1, FR2 and FR3 at the next level that collectively satisfies the highest level FR. Then we go to the physical domain to find DP1, DP2 and DP3 by conceptualizing a design at this level, which satisfies FRs. The decomposition process is proceeded layer by layer until the design reaches the final stage, creating a design that can be fully implemented [19]. This process is illustrated in Fig. 1.

At each level of decomposition, the independence of the FRs must be maintained using the design matrix (DM). Mathematically, the relationship between the FRs and DPs is expressed as

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

Here $\{\mathbf{FR}\}$ is the FR vector, $\{\mathbf{DP}\}$ is the design parameter vector, and $[\mathbf{A}]$ is the DM that characterizes the design.

In general, each entry a_{ij} of $\mathbf{A}$ relates the ith FR to the jth DP.

The structure of $[A]$ matrix defines the type of design being considered [19]. In order to satisfy the independence axiom, $[A]$ matrix should be an uncoupled or decoupled design. $[A]$ matrix is classified into three categories as defined below:

Uncoupled design (*most preferred*): In this design, the $[A]$ matrix is a diagonal matrix indicating the independence of FR–DP pairs. Therefore, each FR can be satisfied by simply considering the corresponding DP. *Decoupled design* (*second choice*): in this design the corresponding $[A]$ matrix is triangular. Therefore, the FRs can be answered systematically FR_1 to FR_n by only considering the first n DPs. This design appears most frequently in real life. *Coupled design* (*undesirable*): in this design the $[A]$ matrix has no special structure.

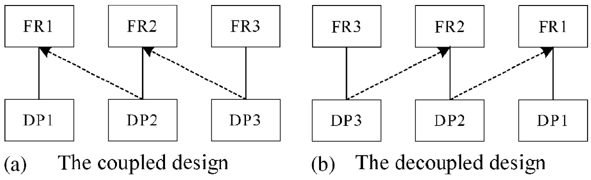

Fig. 2. Conversion from the coupled design to the decoupled design.

Therefore, a change in any DP may influence all FRs simultaneously. In designing systems with AD principles, the coupled design is avoided as much as possible.

The realization of uncoupled designs is rarely possible in the design world. However, coupled designs are abundant, primarily due to the interaction between FRs. Coupled designs lead to complex structures. The process of developing coupled designs results in more repetitive tasks and/or inefficient design structure. As shown in Fig. 2, the negative effect of a coupled design can be eliminated by converting it to a decoupled design. The coupled DM of Fig. 2(a) is based on Eq. (1) as

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & X & \\ & X & X \\ & & X \end{bmatrix} * \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix}. \tag{2}$$

The decoupled design of the coupled design is shown in Fig. 2(b). The decoupled DM of Fig. 2(b) is given as

$$\begin{Bmatrix} FR3 \\ FR2 \\ FR1 \end{Bmatrix} = \begin{bmatrix} X & & \\ X & X & \\ & X & X \end{bmatrix} * \begin{Bmatrix} DP3 \\ DP2 \\ DP1 \end{Bmatrix}. \tag{3}$$

Notice that this matrix is triangular and all upper triangular elements are equal to zero.

For example, the design of an efficient production control system of a factory having an inefficient machine layout is a coupled design. In order to convert it to a decoupled design, an efficient machine layout is designed first [15].

The arrow represents a strong relationship between the corresponding FR–DP pair. The details of AD principles and applications can be found in Ref. [19].

4. Design of office cells using AD principles

4.1. Preliminary design stage

At this stage, the following are performed: determining a project team leader and team members, ensuring people involvement, analyzing the current system, and determining a conversion strategy to office cells. Since office cell design is a large undertaking, a well-motivated project team with a sufficient level of commitment to the project and a good relationship with the project client are key determinants of the project's success. In order to enhance peoples' involvement, related training courses are needed. Naturally, training will also be continued in small groups or one-on-one throughout the life cycle of the project. Current system analysis provides an essential database for the project. Process value analysis (PVA) [23] and value stream mapping [6] are proposed for the current system analysis. PVA identifies all resource-consuming activities involved in manufacturing a product or serving a customer, and labels these activities as being either value-added or non-value-added in nature. Value stream mapping, which is the newest version of PVA, is the visual representation of the material and information flow of a specific product family.

The strategy of conversion to office cells may involve the entire office or it may be the creation of one pilot cell. The proper strategy, based on the current condition of the office, will influence the project's success.

After the preliminary design stage, the following methodology based on AD principles is applied.

Step 1: Choose FRs in the functional domain

The first step in designing office cells is to define the FRs of the system at the highest level of its hierarchy in the functional domain. In this work, the following has been selected as the highest FR:

FR1 = increase/improve organizational performance.

Organizational performance is greatly influenced by organizational structure. If the organizational structure is divided by production functions, this causes the number of non-value-added activities, and hence the lead times and their variances, to increase. Therefore, changing the current structure to a customer-oriented structure is required in order to improve the performance metrics, such as response time to customers, costs, and service qualities.

Step 2: Map FRs in the physical domain

DPs, which satisfy the FRs established in the previous step, are selected through a mapping process between the functional domain and the physical domain. In order to make the correct DP selection, the DP set corresponding to the FR set established previously must be exhaustively generated. The following DP has been selected to satisfy the FR provided above:

DP1 = office cell design.

In order to eliminate non-value-adding activities and decrease lead times and their variances, an organizational

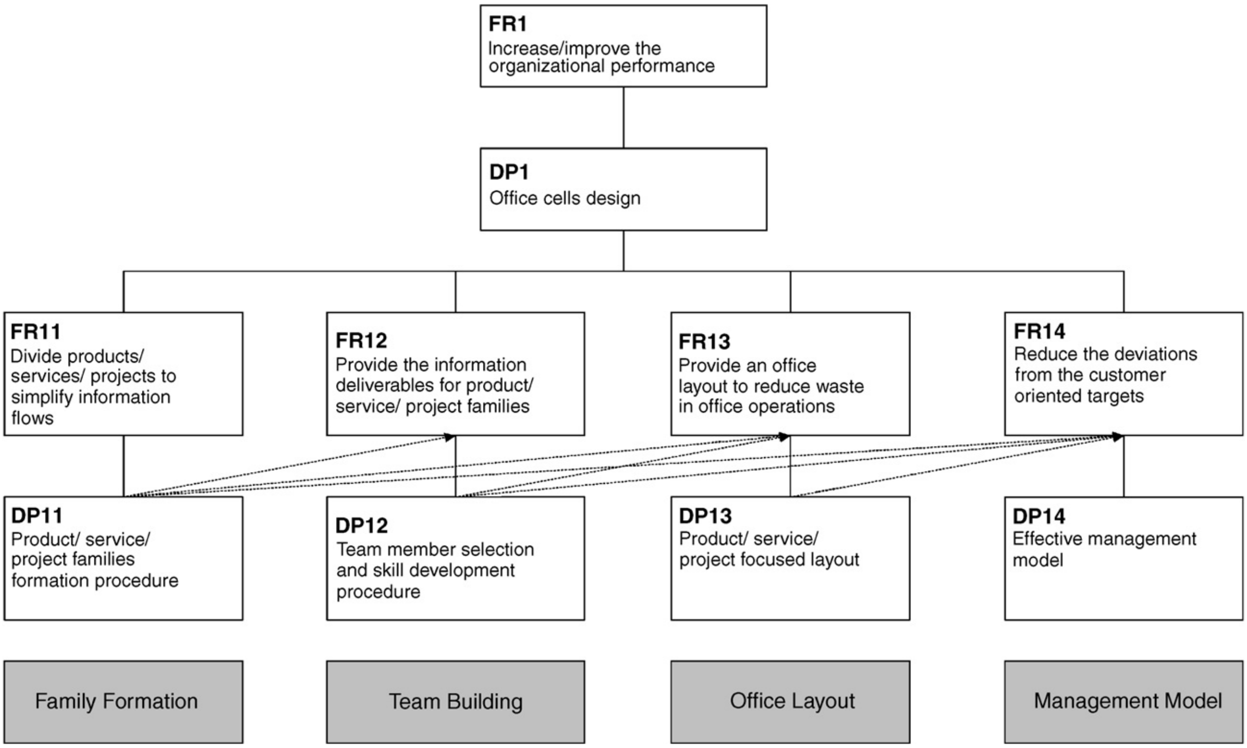

Fig. 3. The decomposition of FR1–DP1.

structure arranged by office cells is needed. Office cells provide a good foundation of teamwork; therefore, their design is a focal point for improvement.

Step 3: Decompose FR in the functional domain—zigzag between domains

If the DPs proposed for satisfying those FRs defined in the steps above cannot be implemented without further clarification, AD principles recommend returning to the functional domain for decomposing the FRs into their lower FRs set. The following lower FRs set is defined for decomposing the FR determined in Step 1 above (see Fig. 3):

FR11 = divide products/services/projects to simplify information flows.

FR12 = provide information deliverables for product/service/project families.

FR13 = provide office layout to reduce waste in office operations.

FR14 = reduce deviations from customer-oriented targets.

Step 4: Find corresponding DPs by mapping FRs in the physical domain

In satisfying the four FRs defined above, we move from the functional domain to the physical domain. The following DPs are in response to the FRs listed above:

DP11 = product/service/project families formation procedure.

DP12 = team members' selection and skill development procedure.

DP13 = product/service/project focused layout.

DP14 = effective management model.

Step 5: Determine design matrix

Once the FR–DP sets are defined in Steps 3 and 4, the corresponding DM provides the relationships between the FR and DP elements. It is important to ensure that the DM, as established, satisfies the IA of the AD principles. If the DM matrix is uncoupled or decoupled, it satisfies the IA of the AD principles [8]. The design equation and the DM corresponding to the FR–DP sets are defined in Eq. (4).

$$\begin{bmatrix} \text{FR11} \\ \text{FR12} \\ \text{FR13} \\ \text{FR14} \end{bmatrix} = \begin{bmatrix} X & & & \\ X & X & & \\ X & X & X & \\ X & X & X & X \end{bmatrix} * \begin{bmatrix} \text{DP11} \\ \text{DP12} \\ \text{DP13} \\ \text{DP14} \end{bmatrix}. \qquad (4)$$

The design given in Eq. (4) is a decoupled design and satisfies the IA. In the matrix above, the symbol X represents a strong relationship between the corresponding FR–DP pair.

In order to simplify information flow and the design of office cells, families of products/services/projects are determined first (family formation). According to these families, team members are selected and skill-development planning for team members is performed (team building). The next step is the physical layout of cells (office layout). The last step is the development of an effective management model for cells to convert from team members to a real team, which is capable of achieving stretch goals [20] (management model).

Step 6: Decompose FR11, FR12, FR13, and FR14 by returning to functional from the physical domain and determining corresponding DPs

4.2. Family formation process (FR11–DP11)

The determination of product/service/project families is very important in designing an effective office cell. Customers, production functions and workload criteria are used to determine families. Therefore, the relationship matrix, including products/services/projects, production functions and customers is prepared first. Information and data workloads are entered into the matrix. Using this matrix, Pareto analysis (ABC analysis) for products/services/projects is performed. Since Pareto analysis is a tool for separating the vital few from trivial many, it is used for deciding which of several products/services/projects to analyze first in terms of workloads. Based on ABC classification, "A" class products/services/projects are selected and each of these products/services/projects is a candidate for forming families. Then the others classified as "B" and "C" are assigned to the candidate products/services/projects considering the similarity criteria which are the production function and/or customer similarities. These similarities are used for that products/services/projects required by same and/or similar customer and production functions are assigned to the same family. At the end, the workload capacity constraint for each candidate family is considered and the final decision is made on family formation. The workload capacity constraint depends on the workload driven from the maximum assignable team members.

The decomposition of FR11 and DP11 is described below depicted in Fig. 4, and its mathematical representation is presented in Eq. (5).

FR111 = determine relations between the functions of producing products/services/projects and customers.

FR112 = arrange and classify products/services or projects according to high workloads of information and data processing.

FR113 = cluster products/services or projects based on similarity criterion/criteria.

FR114 = decide on the final families of products/services/projects.

The corresponding DPs may be stated as follows:

DP111 = products/services/projects—production functions—customers' relationship matrix.

DP112 = information and data workload Pareto analysis.

DP113 = convenient clustering method based on relationship matrix.

DP114 = appropriateness analysis according to workload capacity.

The design matrix for the above set of FRs and DPs are

$$\begin{bmatrix} \text{FR111} \\ \text{FR112} \\ \text{FR113} \\ \text{FR114} \end{bmatrix} = \begin{bmatrix} X & & & \\ X & X & & \\ X & X & X & \\ X & X & X & X \end{bmatrix} * \begin{bmatrix} \text{DP111} \\ \text{DP112} \\ \text{DP113} \\ \text{DP114} \end{bmatrix}. \qquad (5)$$

4.3. Team building process (FR12–DP12)

After fixing the families, the selection of those team members who will process the information and the planning of their skill development are determined according to the specifications of the families. Therefore, the procedures of member selection are formed first. Then the skill development procedure is prepared to ensure maximum utilization of team members' talents.

The decomposition of FR12 and DP12 is described below depicted in Fig. 5, and its mathematical representation is presented in Eq. (6).

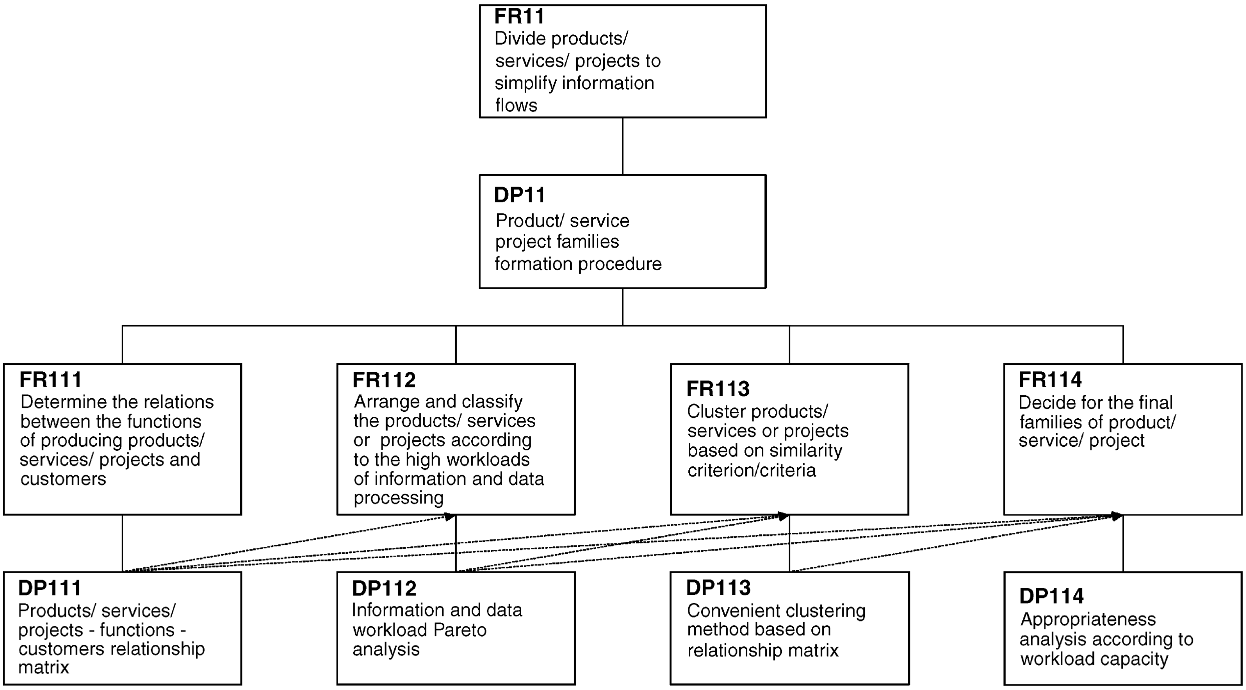

Fig. 4. The decomposition of FR11–DP11 (family formation).

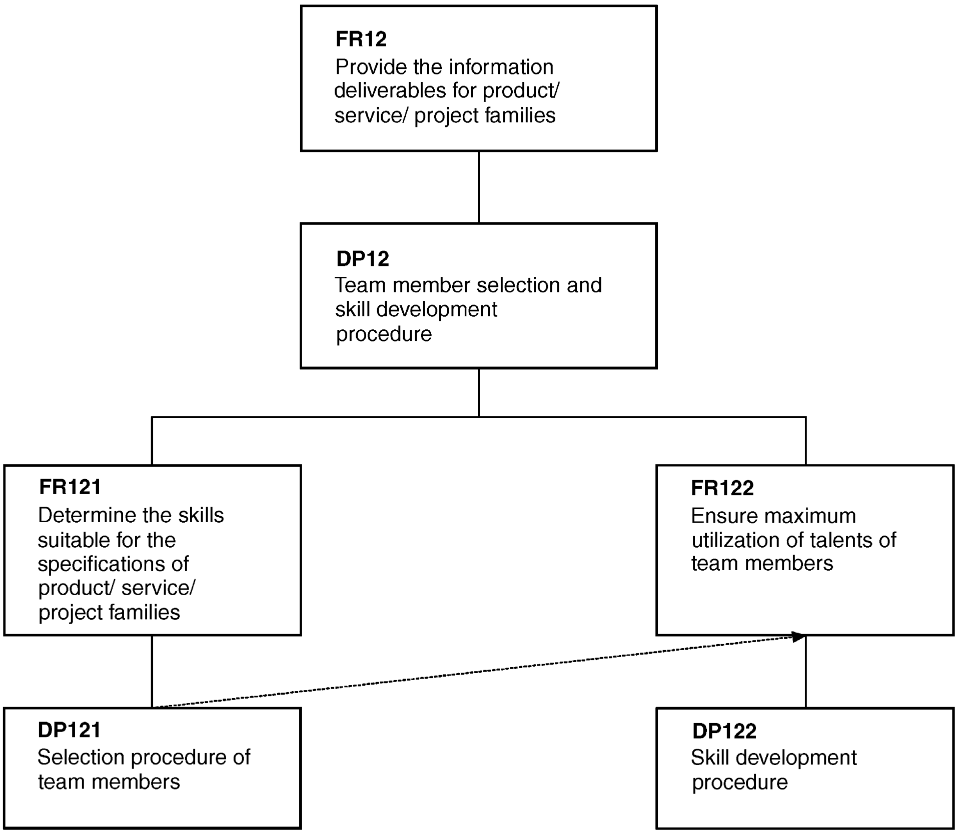

Fig. 5. The decomposition of FR12–DP12 (team building).

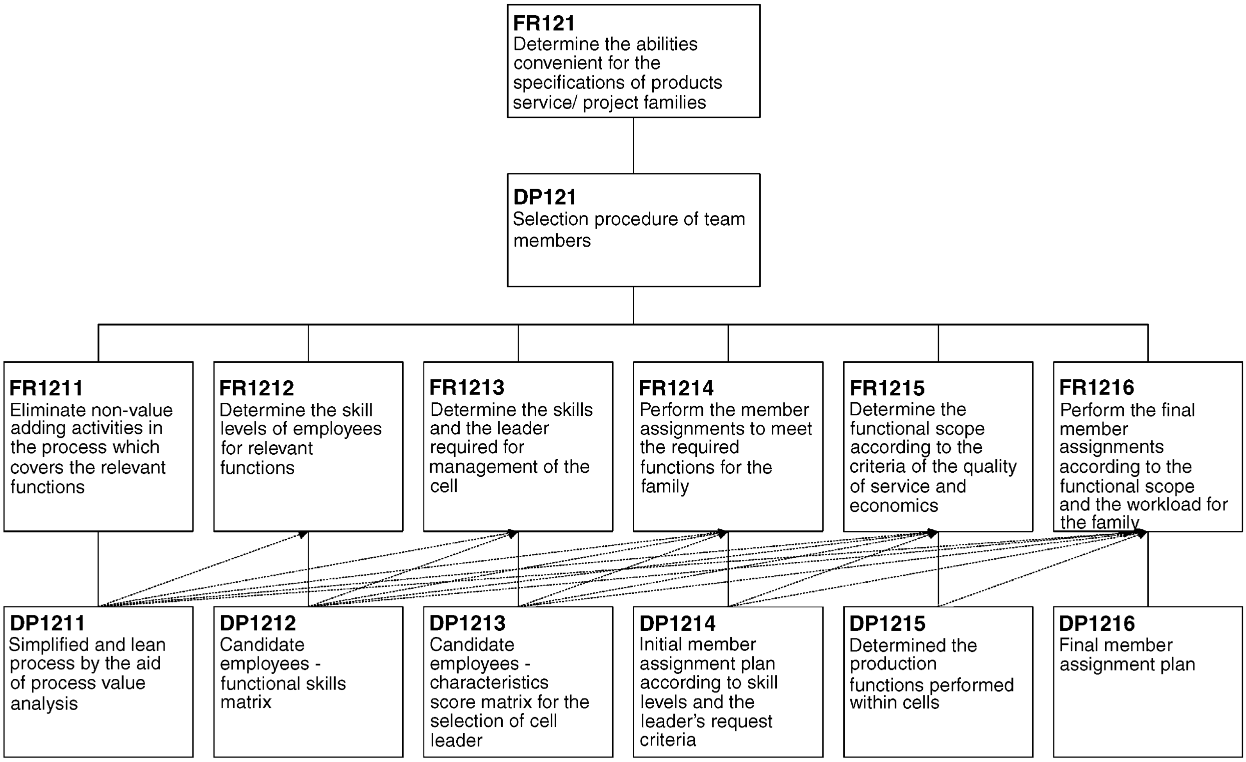

Fig. 6. The decomposition of FR121–DP121 (selection procedure of team members).

FR121 = determine the skills suitable for the specifications of product/services/project families.

FR122 = ensure maximum utilization of team members' talents.

The corresponding DPs may be stated as follows:

DP121 = selection procedure of team members.

DP122 = skill development procedure.

The design matrix for the above set of FRs and DPs is

$$\begin{bmatrix} FR121 \\ FR122 \end{bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} * \begin{bmatrix} DP121 \\ DP122 \end{bmatrix}. \tag{6}$$

In the preliminary design stage with the aid of process value analysis, non-value-added activities are identified, and action plans are determined. The next step is to eliminate these non-value-added activities using the action plans. Thus, the skills matrix [24] between the production functions in relation to the lean process and candidate team members is prepared. Through the skills matrix, candidate leaders are determined by taking into consideration the characteristics expected from a leader. An appropriate leader is chosen among the candidates based on the scores calculated for the characteristics. The state of member candidates in the skills matrix and chosen leader requests are taken into consideration when assigning the initial members into the cell. The initial members and the leader determine the production functions to be performed within cells and, therefore, the level of support services to be used considering desired service quality and economic criteria [25]. Final team members' assignments are accomplished based on the production functions and their workloads within the cell.

The decomposition of FR121 and DP121 is described below depicted in Fig. 6, and its mathematical representation is presented in Eq. (7).

FR1211 = eliminate non-value-added activities in the process, which covers relevant functions.

FR1212 = determine skill levels of employees for relevant functions.

FR1213 = determine skills and leader required for management of the cell.

FR1214 = perform member assignments to meet required functions for the family.

FR1215 = determine functional scope according to the criteria of the quality of service and economics.

FR1216 = perform final member assignments according to functional scope and workload for the family.

The corresponding DPs may be stated as follows:

DP1211 = simplified and lean process using process value analysis.

DP1212 = candidate employees—functional skills matrix.

DP1213 = candidate employees—characteristics score matrix for selection of cell leader.

DP1214 = initial member assignment plan according to skill levels and leader's request criteria.

DP1215 = determined production functions performed within cells.

DP1216 = final member assignment plan.

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} FR1211 \\ FR1212 \\ FR1213 \\ FR1214 \\ FR1215 \\ FR1216 \end{bmatrix} = \begin{bmatrix} X & & & & & \\ X & X & & & & \\ X & X & X & & & \\ X & X & X & X & & \\ X & X & X & X & X & \\ X & X & X & X & X & X \end{bmatrix} * \begin{bmatrix} DP1211 \\ DP1212 \\ DP1213 \\ DP1214 \\ DP1215 \\ DP1216 \end{bmatrix}. \quad (7)$$

After determining team members, the maximum utilization of team members' talents must be ensured. Therefore, members' training needs are determined, and a training plan is designed to meet these needs. In addition, this plan should be extended to continuously maintain skill development.

The decomposition of FR122 and DP122 is described below depicted in Fig. 7, and its mathematical representation is presented in Eq. (8).

FR1221 = determine training needs.

FR1222 = provide continuous skill development environment.

The corresponding DPs may be stated as follows:

DP1221 = team members-training issues relation matrix.

DP1222 = training plan schedule.

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} FR1221 \\ FR1222 \end{bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} * \begin{bmatrix} DP1221 \\ DP1222 \end{bmatrix}. \quad (8)$$

4.4. *Office layout (FR13–DP13)*

The closeness of team members is a major factor in obtaining high performance [1]. For that reason, the equipment needed by team members is placed in the same office area as a cell. In the functional organization, information generally flows from more than one department. Since this situation makes communication, cooperation and coordination difficult, lead time increases dramatically. According to the office cell layout, non-value-added activities are reduced, thereby shortening lead times. In these cells, communication and control, using computers, sending e-mail, waiting for necessary items, and consuming overhead are no longer a major part of operations. Since people are located close together as a team, they are able to provide communication and control to perform the integrated functions by simply talking to each other. Communication and control are built into the process design. The arrangement of a cell's visual display board provides visual communication and control for both the cell and the company. A computer is a valuable tool for individual communication but not for group communication—it lacks public interface. A visual display board provides groups of people with knowing, seeing, and acting abilities as a team [26]. Each display board is updated by team members and shows the name of the cell, mission, vision, cell performance indicators, performance targets, action plans, etc.

The decomposition of FR13 and DP13 is described below depicted in Fig. 8, and its mathematical representation is presented in Eq. (9).

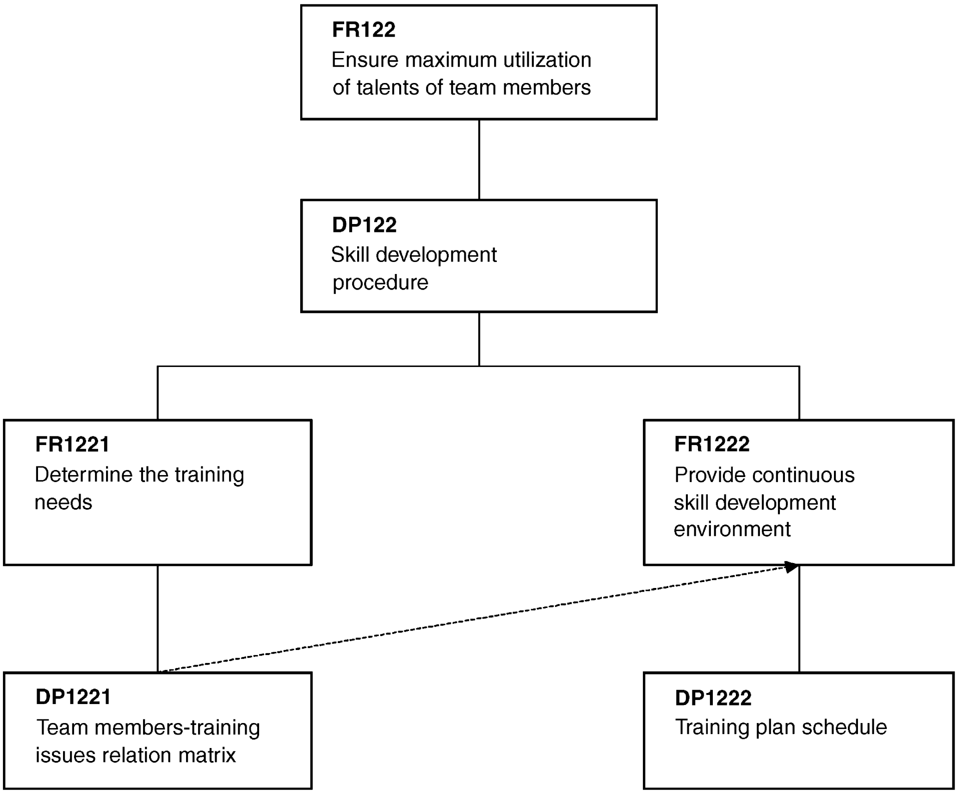

Fig. 7. Decomposition of FR122–DP122 (skill development procedure).

FR131 = reduce waste encountered as the result of difficulties in communication, cooperation, and coordination.

FR132 = reduce waste encountered due to lack of visual communication and control.

The corresponding DPs may be stated as follows:

DP131 = office layout according to information flow.

DP132 = convenient arrangement of cell's visual display board.

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} \text{FR131} \\ \text{FR132} \end{bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} * \begin{bmatrix} \text{DP131} \\ \text{DP132} \end{bmatrix}. \quad (9)$$

4.5. Management model (FR14–DP14)

In previous steps, office cell formation and location are accomplished. The design of an effective management model is required at this stage in order to reduce deviation from the customer-oriented targets. For that reason, creation of team culture and implementation of the Hoshin Kanri approach [27] are proposed. Team culture must be acquired in order to increase members' abilities for working together. Then the Hoshin Kanri approach is established to achieve continuous improvement [28]. Hoshin Kanri differs most radically from "management by objective (MOB)." While information flows in one direction (top down) in MOB, the Hoshin Kanri approach uses two directions (top down and bottom up). Therefore, using the bottom-up approach in Hoshin Kanri, team members determine team performance indicators, targets (goals), and action plans directed to the targets. As a result, Hoshin Kanri helps team focus efforts and achieves results.

The decomposition of FR14 and DP14 is described below depicted in Fig. 9, and its mathematical representation is presented in Eq. (10).

FR141 = increase the ability to work together within a cell.

FR142 = achieve continuous improvement.

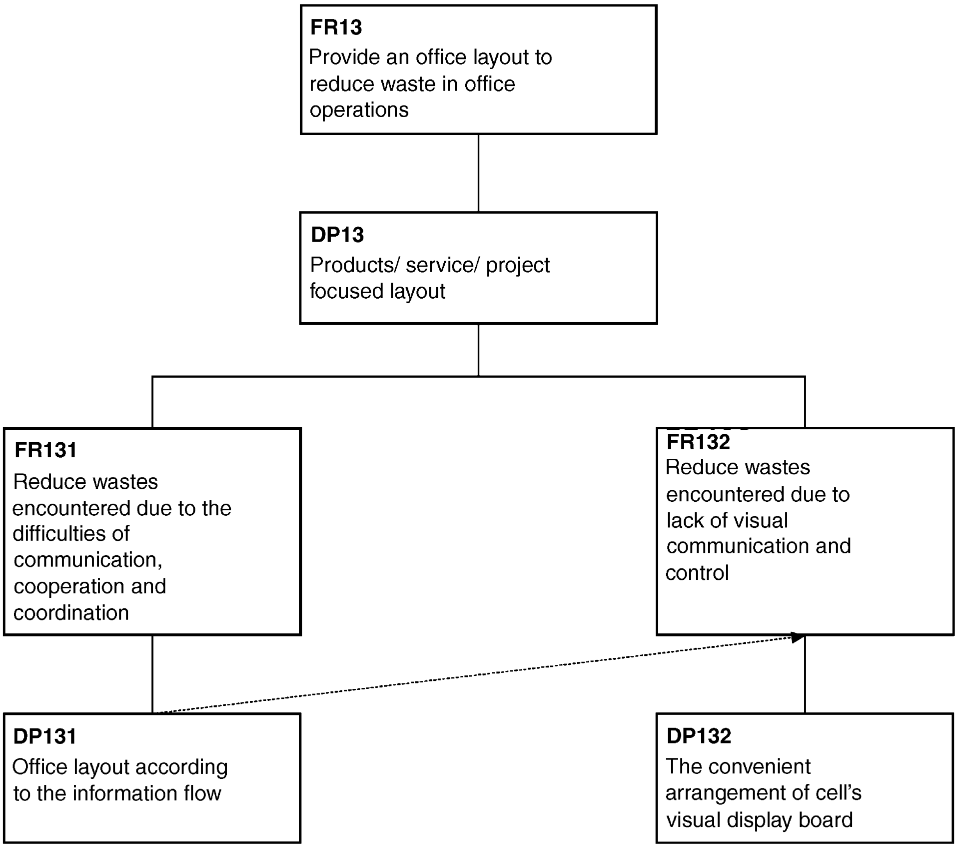

Fig. 8. The decomposition of FR13–DP13 (office layout).

The corresponding DPs may be stated as follows:

DP141 = team culture.

DP142 = Hoshin Kanri.

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} \text{FR141} \\ \text{FR142} \end{bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} * \begin{bmatrix} \text{DP141} \\ \text{DP142} \end{bmatrix}. \quad (10)$$

The mission of a cell is the reason for its existence. The mission stimulates team members for positive changes; however, it does not change itself. For example, NASA's overall mission is to conquer space [29]. It can be explained with more than one statement. However, it should be simple, easy to understand, and easy to remember. Team members determine their mission, which should be the foundation of eagerness for their activities. Only one work statement per cell that is convenient to the mission is determined. Ideally, all processes/functions are expected to be understood and performed by each team member based on the rotation principle. However, the amount of cross-training and job rotation depends on the cell's objectives, the capability of the workforce, and the nature of the technical work itself [4].

In addition, teamwork values should be determined and identified by each team member in order to help establish team culture. Teamwork values are also evaluated and modified by teams as necessary.

The decomposition of FR141 and DP141 is described below depicted in Fig. 10, and its mathematical representation is presented in Eq. (11).

FR1411 = establish clear scope in the direction of the cell's goal.

FR1412 = provide working environment for teams.

The corresponding DPs may be stated as follows:

DP1411 = work statement convenient to the mission of the team.

DP1412 = teamwork values.

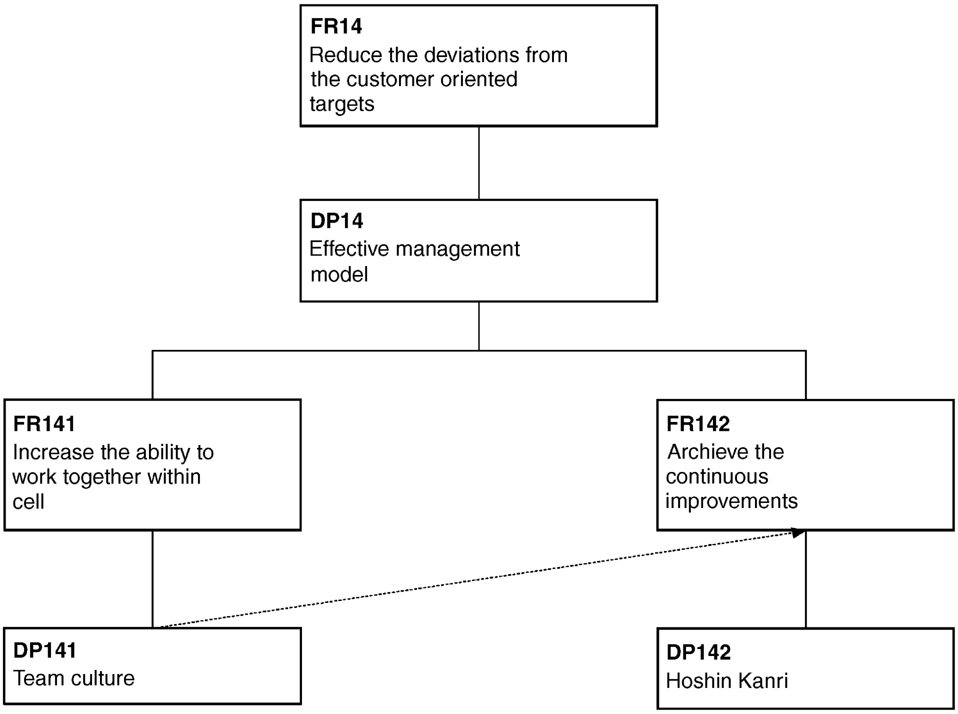

Fig. 9. The decomposition of FR14–DP14 (management model).

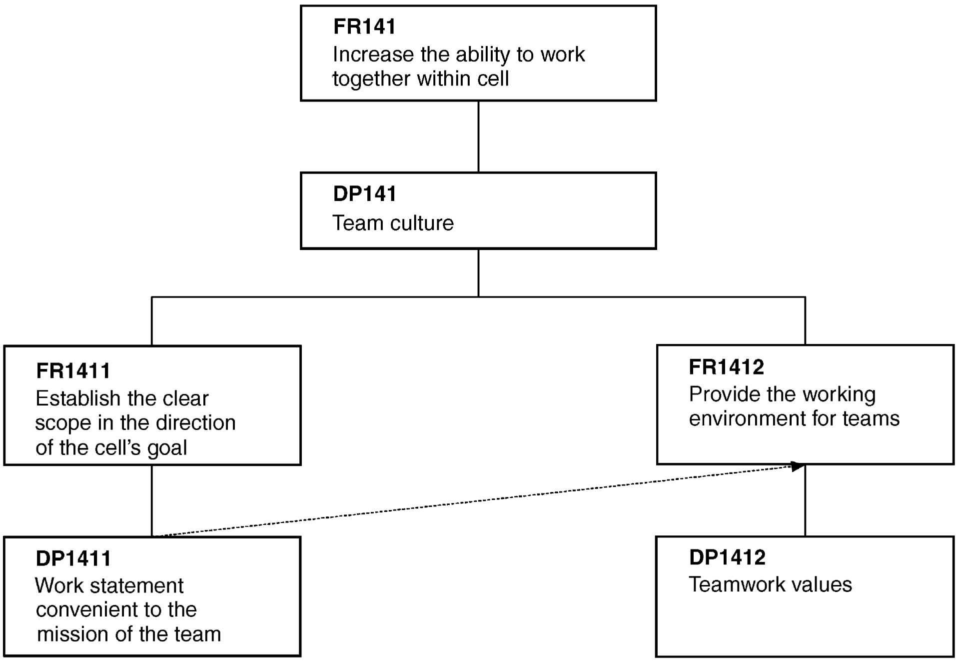

Fig. 10. The decomposition of FR141–DP141 (team culture).

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} \text{FR1411} \\ \text{FR1412} \end{bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} * \begin{bmatrix} \text{DP1411} \\ \text{DP1412} \end{bmatrix}. \qquad (11)$$

In order to achieve continuous improvement of the cell, team members determine cell performance indicators and targets at the scope of Hoshin Kanri. Then a goal-based incentive system is built to increase motivation [30]. Within the content of goal-based incentive system, group-based incentive system is suggested besides individual one. Monetary and/or non-monetary types of rewards are determined based on the goals. Since increasing cell flexibility is very important to attain determined targets, an action plan is prepared based on the skills matrix in order to increase the multi-functional quality of team members. In contrast with the central organization (where major functions are accomplished in different departments), team members have to perform multiple (or all) functions within the cell. Multi-functional quality of team members is defined here as cell flexibility and measured by multi-functional rate using red apple approach [24]. Following this is the focus on eliminating the non-value-added activities in order to reduce lead times. Eliminating the non-value-added activities can be expanded further; however, this will not be covered here. The transfer cost of products/services/projects is yet another important issue on which to focus in order to reduce deviation of the cell budget. Lead-time reduction aids in the reduction of transfer cost of a product/service/project, defined here as the portion of the cost incurred within the cell, which is allocated to that specific product/service/project. This portion is transferred to the customer (or the customer cell) as a transfer cost.

The decomposition of FR142 and DP142 is described below depicted in Fig. 11, and its mathematical representation is presented in Eq. (12).

FR1421 = provide a means to increase motivation.

FR1422 = provide a means to increase flexibility within a cell.

FR1423 = reduce non-value-added activities.

FR1424 = reduce deviations of cell budget.

The corresponding DPs may be stated as follows:

DP1421 = incentive system convenient to determined targets.

DP1422 = increased multi-functional rate.

DP1423 = reduced lead times.

DP1424 = reduced product/service/project transfer cost.

The DM for the above set of FRs and DPs is

$$\begin{bmatrix} \mathrm{FR1421} \\ \mathrm{FR1422} \\ \mathrm{FR1423} \\ \mathrm{FR1424} \end{bmatrix} = \begin{bmatrix} X & & & \\ X & X & & \\ X & X & X & \\ X & X & X & X \end{bmatrix} * \begin{bmatrix} \mathrm{DP1421} \\ \mathrm{DP1422} \\ \mathrm{DP1423} \\ \mathrm{DP1424} \end{bmatrix}. \quad (12)$$

So far, the design of the office cell is completed (see Fig. 12). A complete DM for office cells is prepared in order to assure that leaf-level design decisions are consistent. As shown in Fig. 13, inconsistent relations do not exist between leaf-level DPs and FRs.

In addition, cell monitoring and performance development are issues that should be considered for continuous improvement. Therefore, the performance development procedure has been prepared according to AD principles; however, it has not been included in this paper.

5. Implementation of office cells

This developed road map was used in a loyalty-marketing group of companies for office cell designs. Loyalty projects are usually performed for banks and communication companies. These companies require organizing a significant loyalty system for promotion of the end users in order to increase the usage of their credit cards and the GSM operating system. Loyalty projects usually contain campaigns in a manner of accumulation points based on end users' expenses and selection of gifts according to points or points plus credits given. The group of companies serving on this project implements the following functions:

- Determines the gifts as products.
- Selects and manages the suppliers for determined products and services.
- Establishes creative works, publishing, and delivering the gift catalogues.
- Receives and processes demands of the end users, based on the points earned proportional to the level of usage.
- Stores products in the warehouse.
- Repackages products as gifts and ships them to the end users.
- Organizes and provides travel services as gifts, such as flight tickets and vacations.

The group consists of four companies, which are below-the-line advertising, direct marketing, knowledge-management, and import-distribution companies. Below-the-line advertising and direct marketing

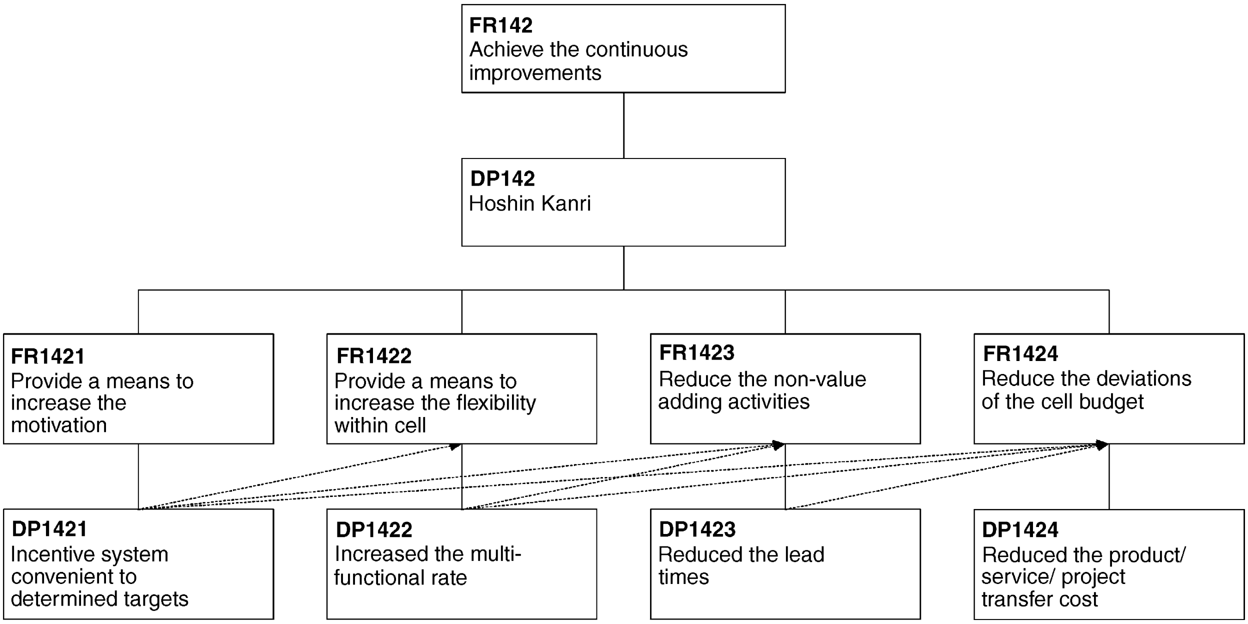

Fig. 11. The decomposition of FR142–DP142 (Hoshin Kanri).

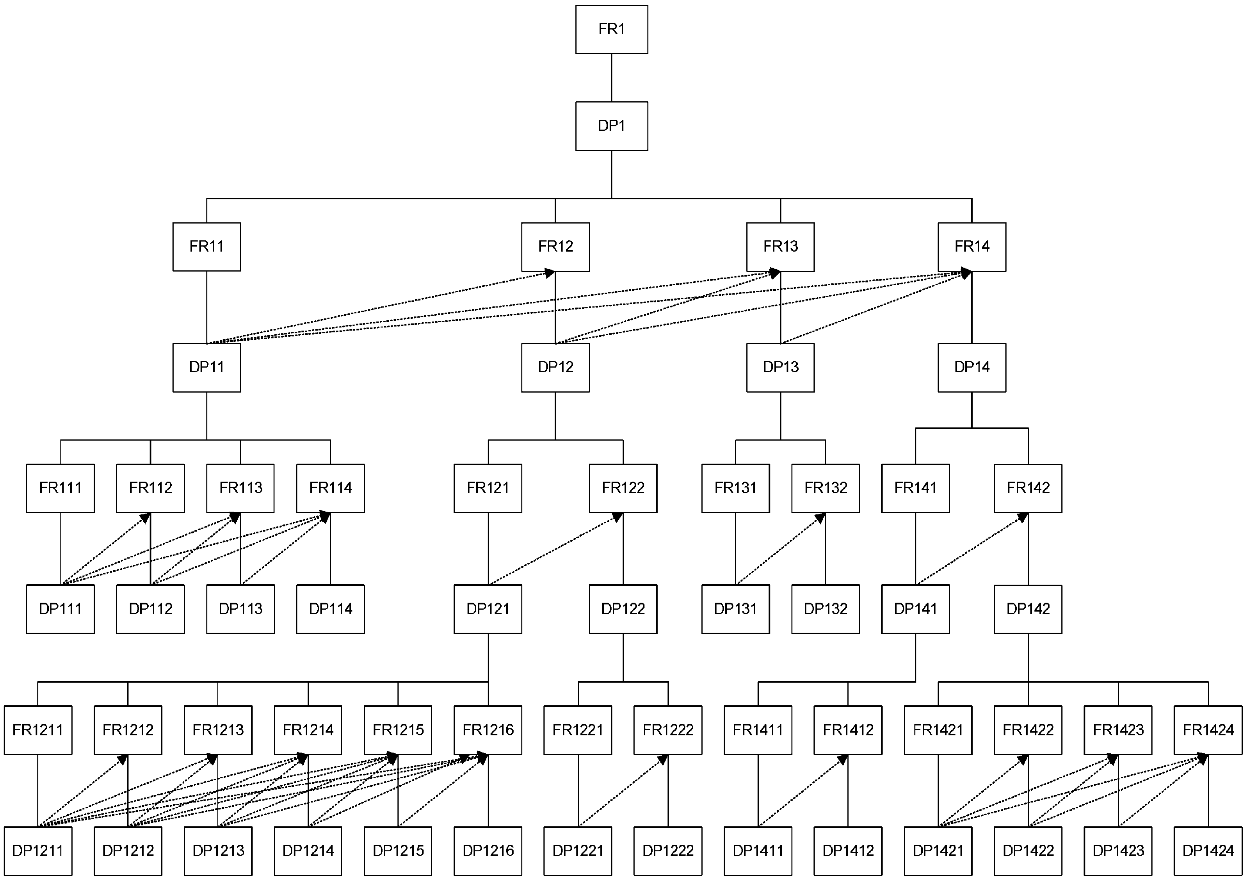

Fig. 12. The decomposition of office cell design.

Complete Design Matrix for Office Cells			DP11				DP12								DP13		DP14					
							DP121= Selection procedure of team members						DP122= Skill development procedure				DP141= Team culture		DP142= Hoshin Kanri			
			DP111= Products/services/projects – functions - customers relationship matrix.	DP112= Information and data workload Pareto analysis	DP113= Convenient clustering method based on relationship matrix.	DP114= Appropriateness analysis according to workload capacity.	DP1211= Simplified and lean process by the aid of process value analysis	DP1212= Candidate employees-functional skills matrix	DP1213= Candidate employees-characteristics score matrix for the selection of cell leader	DP1214= Initial member assignment plan according to skill levels and the leader's request criteria	DP1215= Determined the production functions performed within cells	DP1216= Final member assignment plan	DP1221= Team members-training issues relation matrix	DP1222= Training plan schedule	DP131= Office layout according to the information flow	DP132= The convenient arrangement of cell's visual display board	DP1411= Work statement convenient to the mission of the team	DP1412= Teamwork values	DP1421= Incentive system convenient to determined targets	DP1422= Increased the multi-functional rate	DP1423= Reduced the lead times	DP1424= Reduced the product/service/project transfer cost
FR11		FR111= Determine the relations between the functions of producing products/services/projects and customers	X																			
		FR112= Arrange and classify the products/services or projects according to the high workloads of information and data processing.	X	X																		
		FR113= Cluster products/services or projects based on similarity criterion/criteria.	X	X	X																	
		FR114= Decide for the final families of product/service/project.	X	X	X	X																
FR12	FR121= Determine the skills suitable for the specifications of product/services/project families	FR1211= Eliminate non-value adding activities in the process which covers the relevant functions	X	X	X	X	X															
		FR1212= Determine the skill levels of employees for relevant functions	X		X	X	X	X														
		FR1213= Determine the skills and the leader required for management of the cell	X		X	X	X	X	X													
		FR1214= Perform the member assignments to meet the required functions for the family	X	X	X	X	X	X	X	X												
		FR1215= Determine the functional scope according to the criteria of the quality of service and economics		X	X	X	X	X	X	X	X											
		FR1216= Perform the final member assignments according to the functional scope and the workload for the family		X	X	X	X	X	X	X	X	X										
	FR122= Ensure maximum utilization of talents of team members	FR1221= Determine the training needs	X	X	X	X	X	X	X	X	X	X	X									
		FR1222= Provide continuous skill development environment	X	X	X	X	X	X	X	X	X	X	X	X								
FR13		FR131=Reduce wastes encountered due to the difficulties of communication, cooperation and coordination.	X	X	X	X	X				X	X			X							
		FR132= Reduce wastes encountered due to lack of visual communication and control.					X				X	X			X	X						
FR14	FR141= Increase the ability to work together within cell	FR1411= Establish the clear scope in the direction of the cell's goal	X	X	X	X	X	X	X	X	X	X			X	X	X					
		FR1412= Provide the working environment for teams	X	X	X	X	X	X	X	X	X	X			X	X	X	X				
	FR142= Achieve the continuous improvements	FR1421= Provide a means to increase the motivation					X		X	X	X	X	X	X	X	X	X	X	X			
		FR1422= Provide a means to increase the flexibility within cell	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		
		FR1423= Reduce the non-value adding activities	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		FR1424= Reduce the deviations of the cell budget	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Fig. 13. A complete design matrix for office cells.

companies aim to manage the campaigns for banks and GSM companies. The knowledge-management companies provide information technology and consulting. For each company, solutions based on the databases of campaigns are developed, and current marketing and advertising services in the information technology environment are implemented. The import-distribution company imports and markets all kinds of electrical household appliances. Also, the last two companies are suppliers for the first two companies. The effort for designing office cells focused on 38 employees from the below-the-line advertising and direct marketing companies.

Loyalty projects are performed through four different departments: project management, operations and storage, creative studios, and travel services. Data entry and reporting, purchasing, and storage and shipping are sections within the operations and storage department (Fig. 14).

Communication, cooperation, and coordination are required among all departments in order to complete the project. This situation causes non-value-added activities to increase and lead times to lengthen, including response times to customers. The idea of building office cells based on teams is developed to overcome these problems and to increase the quality of services.

In the preliminary design stage, activities explained by the developed methodology were performed. PVA, which is one of the suggested approaches for current system analysis, was performed by the activity-based costing project before the office cell project started. Therefore, PVA was also used for the design of office cells.

The pilot cell strategy was chosen for implementation. The project took 8 months before the planned pilot cell (office cell 1) was realized. During the successful testing period of 3 months, the other planned cells were built simultaneously at the same location.

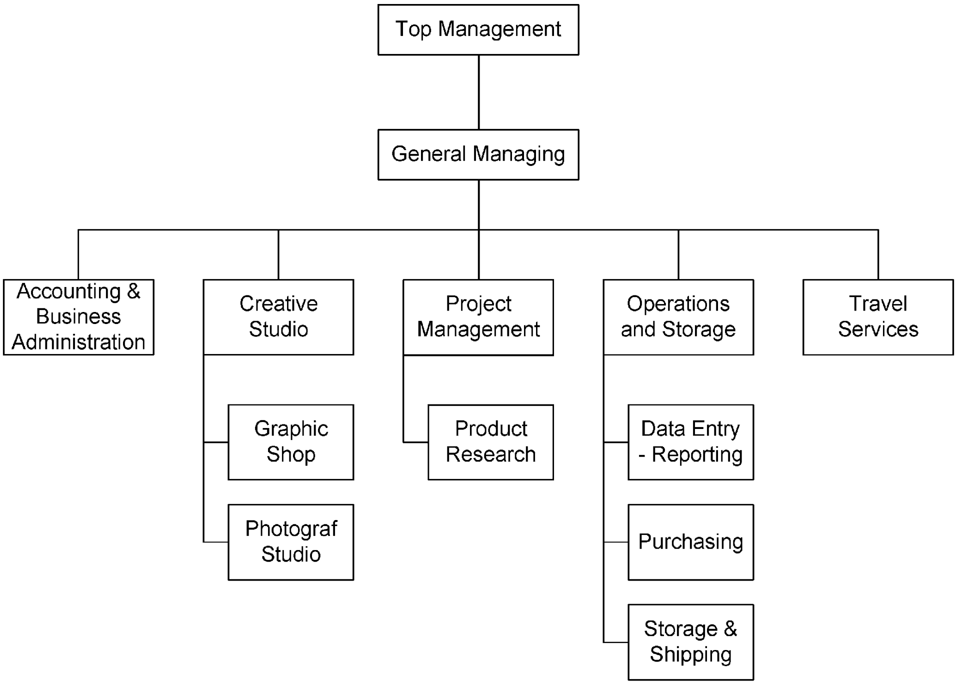

Fig. 14. The organizational structure before cellular system.

5.1. Family formation process (FR11–DP11)

The formation of project families began following the preliminary design stage, with the aim of simplification of the information flow. Each of the customers was considered as a project. Firstly, ABC classification using Pareto analysis was realized and three projects were determined as candidate project families. Then other eight projects were assigned to these candidate families according to customer and production function similarities.

The available number of staff and the maximum assignable members to a cell were taken into consideration for determining the number of office cells. The number of team members was required not to exceed eight, including team leaders. The team size was determined based on the business environment. The size of team had to be large enough to enable team dynamics and to allow a variety of ideas and skills, yet small enough to enable cohesiveness of the team members [31]. According to the maximum assignable number of eight members, the maximum workload was determined and accepted as a capacity constraint. Finally all the families were evaluated and one project was reassigned from the family with excess workload to the convenient one in terms of workload. As a result, three final project families containing three or four projects were formed.

5.2. Team building process (FR12–DP12)

The procedures for selecting team members based on project families and skill development were applied in a similar manner as before. The skill matrix between candidate team members and production functions were initially built. As an example Fig. 15 shows a skill matrix built for office cell 1. After cell management skills were determined based on the skills matrices, cell leader selection and initial members' assignments were performed. The selected team members determined the functions performed within cells and the support services (see Table 1). Based on the allocations of functions, the redesigned organization based on office cells is shown in Fig. 16. According to these allocations, the final assignment of team members into cells was realized by means of re-evaluating the proposed team members. The organizational structures of office cells were customer-oriented.

As shown in Fig. 16, a central purchasing department was built as a common service department. Several employees who were available from the purchasing department formed this department in order to supply

Fig. 15. The skills matrix of office cell-1. (The apple is divided into four portions. When the skill level is increased, one portion of apple becomes red.)

Table 1
The functions performed within cells and the support services being used

The functions included in the cell	The functions excluded from the cell
Project planning	Acc. & Business adm.
Project control	Creative
Order management	Central purchasing
Invoicing	Storage
Reporting	Travel services
Data entry	
Call center	
Returns	
Budgeting	

common gifts belonging to more than one cell. Other purchasing employees, prior to cellular structure, were divided between cells. In other words, this approach delegated most of the purchasing authority, except purchasing common gifts, to the cells.

5.3. Office layout (FR13–DP13)

An office layout that was convenient for the structure of office cells was determined. All cells were placed in offices adjacent to each other. Team members and their equipment were arranged according to the information flow within the cell. As a result of cellular arrangement, a 30 percent savings in the office area was obtained.

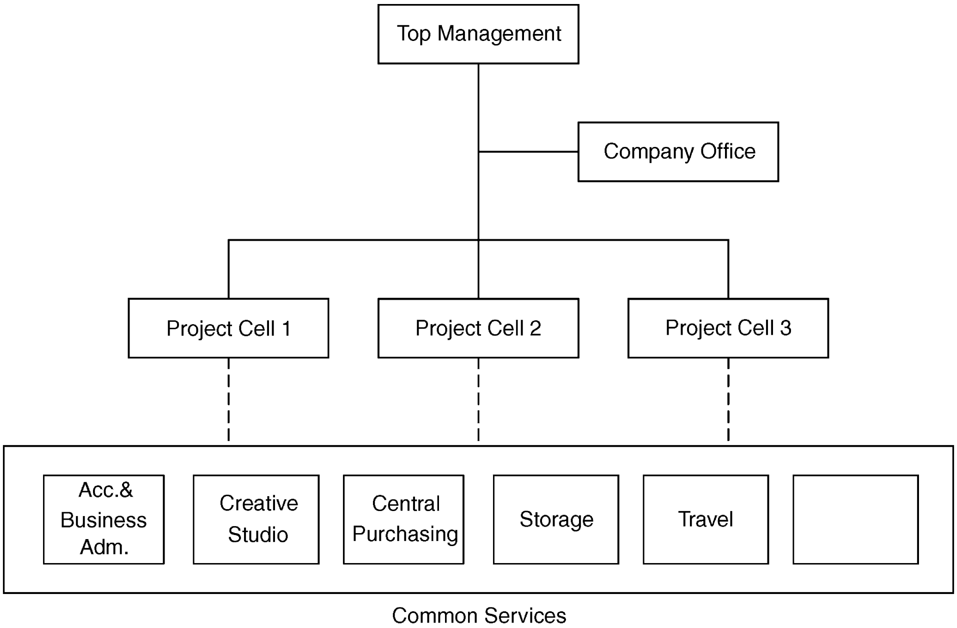

Fig. 16. The organizational structure after cellular system.

In addition, a visual display board was arranged for each cell. These boards facilitated visual communication and control.

5.4. Management model (FR14–DP14)

This stage needed to ensure the continued effectiveness of cells in operation. For this reason, the formation of a team culture and a Hoshin Kanri culture were started. Within the scope of each team, it was ensured that team members determined their mission, work statements, and teamwork values of their own cells. At the first step of Hoshin Kanri, the cell performance indicators and the performance targets were determined. With respect to these plans, the action plans were prepared for the targets determined.

During the six-month period after the pilot office cell 1 was built, improved activities were realized, and improved performance values were attained, as shown in Table 2. The lead time was reduced from five days to three days after development of the office cell. Since only one team was responsible for the customer order, that team could focus on its customers. This caused the end user satisfaction rate to increase from 75 to 85 percent at call center telephones. A survey with 500 respondents was conducted to measure these end user's satisfaction rates. Since team members were located in close proximity to each other, they learned the others' jobs and assisted in bottleneck tasks. Therefore, the team member flexibility rate increased from 21 to 50 percent. The flexibility rate here was introduced as the percentage of three and four red portions from the whole apple for all team members. The team members discussed and decided their skill levels measured by the number of red portions of their apples for each function within the cell. To increase the multi-functional quality of team members, an individual intensive system was built. The reward types in a group-based incentive system were also determined in Table 3, depending on the weighted percentage of target performances achieved.

6. Conclusion

This paper presents a systematic road map for designing office cells using axiomatic design principles. This road map is used for reducing the non-value-added activities in office functions and for obtaining considerable simplicity and benefits toward building a lean enterprise. An application of the independence axiom was proposed throughout the design process to develop a road map for office cells. Using this axiom, design goals became explicit rather than implicit. Therefore, during the office cell project, resistance of middle management decreased and people involvement increased. This, of course, has helped effectively facilitating a design process that is customer satisfaction oriented.

Table 2
Performance values of office cell-1

Performance indicators	Performance before office cells	Target performance	Performance after office cells
Time for creation of a project and development of its software	120 days	90 days	100 days
Lead time[a]	5 days	3 days	3 days
Return products rate	5%	2%	3%
Customer satisfaction rate at call center telephones	75%	90%	85%
The flexibility rate for team members[b]	21%	75%	50%
Deviations from the budgets of the projects	±20%	±10%	±10%

[a]Average time between the customers' (end user) placement of orders and the delivery of the ordered gifts to a transport company.
[b]The flexibility rate here is introduced as the percentage of three and four red portions from the whole apple for all team members.

Table 3
Team reward types

Team reward type	Weighted percentage of target performances achieved (threshold value and upper)					
	70	75	80	85	90	95 or upper
Raising salaries						√
Premium					√	
Bonus				√		
Leaving of absence			√			
Training		√				
Gift	√					
Recreation	√					

The proposed procedure was implemented to meet the requirements that arose from the outcomes of an active project performed in a firm. The previous centralized organizational structure acted as a burden to the firm's communication and information flow among several departments in resolving customer complaints. There were high lead times and customer dissatisfaction. However, implementation of the office cells and decentralization of the organization enabled cooperation of several functional departments in the solution process and creation of continuous improvement resulting from improved participation. Clear definition of responsibilities also provided ownership and customer focus. Since team members were located close to each other, they could improve their skills by reciprocal interactions and assist others in carrying out bottleneck tasks. A significant improvement in team member flexibility rate was observed.

The functional requirement and design parameter sets in office cell design might change according to the designer. Future research could involve a different design developed by another designer that would be compared to the presented road map using the information axiom. Research for generating the information content of design matrices is in progress.

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