THE ROLE OF SYSTEM THEORY IN NEW PRODUCT DEVELOPMENT: AN INVESTIGATION FOCUSING ON LEAN AND SIMULTANEOUS ENGINEERING

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ABSTRACT
The forces on the firms could be summarized in five dimensions namely, competition through new technologies, new entrants with their low cost of investments, suppliers with their high authority, buyers with their extreme freedom to switch to low cost suppliers, and high range of similar products on the market. Reducing price to compete with firms in the global market makes it compulsory to analyze the continually changing market demands and produce what customers really need and launch the product rapidly on the market to conquer the cheap products which ensures the company’s existence. Accordingly, more companies are getting conscious over the benefits of Front-End models of innovation comparing to traditional Back-process (Monczka et al., 2000). Therefore, it is necessary to take a closer look at the whole potential aspect of improvement in firm’s managerial process, especially at the fuzzy front end period by new product development to achieve higher success. One of the important aspects during this period of development is the involvement of external resources such as supplier and customer. Involving suppliers in product development has been namely explored to reduce costs of product and development, to decrease development time, and to improve product quality (Wasti & Liker, 1997). In this paper, we will discuss the success factors and barriers of involvement of external resources and the

KEYWORDS
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ways how this process can be managed.

1. Introduction

Managing innovation is a challenge for companies because they have to cope with the complexity of today’s market. Improving a systematic process for such a management strategy is a goal of many companies and enumerates as a factor for competitive advantages. Austin and Peters (1989) identified four critical factors to become excellent companies which are people, care the customer, constant innovation and leadership.

Speed of new product introduction is related to cumulative capabilities of firms. In this context, the supply chain is playing a prominent role for simultaneous improving of multiple dimensions of manufacturing performance. Therefore, supply chain is one of the main subjects of lean practices while other practices of lean like TPM, JIT, and TQM are frequently mentioned in literature.

Surely, such an integrated management philosophy supports the competitive advantage which is highlighted through continuous improvement. There are different interpretations of competitive advantages. However, the key parameters of competitive advantage are listed as below (see Table 1; Boyer, 1998).

<table>
<thead>
<tr>
<th>Table 1. Competitive advantages</th>
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<tr>
<td>Cost</td>
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<tr>
<td>Reduce inventory;</td>
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<tr>
<td>Increase capacity utilization;</td>
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<tr>
<td>Reduce production costs;</td>
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<tr>
<td>Increase labor productivity.</td>
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Lack of investigation of product design has negative influence on downstream processes in manufacturing and may cause an increase in manufacturing costs. To avoid this and ensure the long-term competitive advantage of companies, suppliers have to be part of product development process in early stages. Then, they could support the companies by most of the aforementioned factors. Suppliers make a significant contribution for competitive advantages of their customer, in terms of innovation and operational performance through quality, delivery time and reliability as well as flexibility (Wasti & Liker, 1997).

There are different comprehensions of core principles by lean strategy: Identification and elimination of waste e.g. WIP inventory or delays in flow time, generating smooth flow (Kanban pull signals), supplier partnerships, mixed-model production, pursuing continuous improvement, TQM, TPM, design for assembly, visualizing key indicators of production and respect for people. Same as Six Sigma, it could be observed different developments and interpretation by adopting lean. First, Lean is identified as a set of tools and has been adopted within production management to improve its process. More recently, it made a progress toward operational philosophy of management, which can be shared by customers, employees, and suppliers. Therefore, the proponents of lean production disclosed that supplier partnership is one of the main principles of Toyota system. Accordingly, the Japanese long-term contracts between buyers and supplier are one of their well-considered advantages (see Figure 1; Womack et al., 1990).

With increase of global competition, the need for product novelty is increasing which makes it necessary to answer high market demand with frequently innovation and shortage of product development cycles. The principles mentioned in DIN EN ISO 9001/9004: 2000 are used to improve performance of the organization and it consists of following eight aspects:
Customer orientation;
Leadership;
Involvement of people;
Process approach;
System-oriented management approach;
Continuous improvement;
Factual approach to decision making;
Supplier relationships for mutual benefit.

One important point is to develop products by considering four major points which are time, quality, cost, and more importantly the interrelation of all these parameters with each other. To reach this goal many companies gaining from one approach by integrating their supplier and customer in the fuzzy front end of product development (Ragatz et al., 1997).

One major point is the complexity of products. The products are getting more complex which cause simultaneously increasing the complexity in internal process. Therefore, it is not possible to cope with upcoming challenges during the development process reclusively. Otherwise, the know-how of producing each part in own factory is not given in every company. Even producing and developing internally increases the firms’ risks so that the need for out-sourcing is increasing. This may have a positive effect on performance because the firms are focusing on their core competence and incorporate innovations from external sources. Therefore, in the literature, the role of supplier in the innovation process has been extensively discussed (Roy et al., 2004). One major approach is Simultaneous Engineering, which means developing and even manufacturing of products concurrently with suppliers. We can classify the contribution of supplier regarding the design, development and engineering of components to increase the efficiency and effectiveness. The cooperation with both supplier and customer must be however, simultaneously in every stage of product development (see Figure 2).
Figure 2. Continuous cooperation between Firm-Supplier-Customer

Furthermore, Kleinschmidt et al. (1997) explored that the successful product or service related directly upon whether the needs of customers have been considered and moreover if the product gives customer unique usage. Particular needs of customers are superior quality. Garvin (1987) declared in his extended quality performance model that quality management practice has a direct impact on product quality performance (e.g. conformance, performance, feature, reliability) as well as operational performance (e.g. cost, delivery) and they both have a mediator effect on business performance (financial). These acknowledgements make it clear that products which are more affiliated to customer needs are more successful than the new product developments which are developed solely on new technology. Therefore, there is a need to focus on product development with contribution of external resources, mainly those, which have close relation to customers.

In the last two decades many academics’ researches are done to analyze the successful development of new products. As a result the positive usage of external resources for NPD is now more apparent for the companies and managers. While just 20% of the most technology-intensive companies were relying heavily on external sources of technology in 1992, the number increased to 85% by 2000 (Roberts, 2001). The shift from closed innovation to open innovation considering external parties can be done for four reasons: increasing mobility of workers, advent of venture capital, external option for ideas and increasing capability of suppliers (Chesbrough, 2006). But contributions cannot be as open as it sounds. The companies are in need of some control methods.

Ohno (2009) reported how Toyota has developed the new concept for supplier involvement which benefits from both innovative features and faster launches of products and their support. This contribution begins from simple consultation for design to make the suppliers responsible for their whole design components which will be used in the final product. The positive effects of supplier and customer involvement are demonstrated in some literature with product development topic (Dröge et al., 2000; Dyer, 1996; Liker et al., 1996).

2. Successful integration of supplier in product development

Ohno (2009) has identified seven types of wastes, especially in the production process which are: overproduction, waiting, transporting, inappropriate processing, inventory, movement, and defects. In a common contribution these wastes should be translated for supplier integration process and minimize all types of wastes.
One major point by optimizing the innovation capability in companies is the use of cross-functional teams for new product development. Coordination and communication across different functional groups make it possible to recognize the limitations from different perspectives and save money. Therefore, it makes sense to expand this functional group up to extensive external communications with suppliers.

Partnerships are needed in all internal customer-supplier relations, in all external supplier relations, in external customer relations and between managers and their subordinates. The clue is to build a total system of customer-supplier relations, which are working close together in their own interest for reducing waste. This requires a lot of the managers.

Deming (2000) advocates that there is a need to build a total system of external customer/supplier relations with a common goal to reduce waste. The greatest contribution of Deming was to view an organization as a system and a system cannot understand itself. Therefore, such a system needs manager with ability of System of Profound Knowledge (SoPK) and it consists of following four parts:

- Appreciation for a system: understanding the overall processes involving suppliers, producers, and customers of goods and services;
- Knowledge of variation: the range and causes of variation in quality, and use of statistical sampling in measurements;
- Theory of knowledge: the concepts explaining knowledge and the limits of what can be known;
- Knowledge of psychology: concepts of human nature.

Nevertheless, since the human factor is involved in the whole innovation process, it is the key element of successful innovation (Vrakking, 1990). Unfortunately, the role of human (customers, employees, etc.) in lot of management methods is considered quite indirectly (Heeg, 2013). He suggested to adopt a method which is focused on human interventions and emphasized the human actions and attitudes. Morcillo (1997) agrees with this opinion and he states that:

“There are no good technologies or good innovations without competent people who can adequately use them and get benefit from them. At the same time, no competent people can be available if there is not, first, a business project defining the role that technology and innovation must play and creating the necessary and sufficient conditions for catalyzing and channeling aptitudes, capacities and attitudes of the individuals towards the established direction.
Therefore, the social aspects of such a process should not be neglected which is influenced its success. “

Altogether, two pillars of Toyota production systems are continuous improvement and respect for people (i.e. employees, suppliers, customers, investors and the community). To deal appropriately with the human, Heeg (2013) emphasized the human nature of decision making which is inherently based on not rational-logic but also emotional-logic. These points underline the importance of knowledge of psychology as Deming (2000) has defined. Deriving out of this point, the prerequisite of building a successful partnership, regarding to Toyota’s perspective, are the core values such as trust and respect.

Brunner (2001) describes the cooperation with the supplier, from Japanese perspective as a trustworthy in a mutual exchange of information. A lack of trust has been cited as a main reason of fail in business collaborations. To establish such a trust culture, it is necessary to proof internal principles and remit to suppliers. (Gemünden & Walter, 2000). According to Brunner (2001) Toyota management culture offers four principles to develop a "value-added culture" as:

- Focus on systems and processes, not results;
- Open decision-making;
- Spontaneous information and coordination;
- Individual initiatives and self-control of the partner.

In Table 2 the main factors influencing suppliers’ integration in product development are listed. They have positive impact by integration process. Schiele (2010) reported how successful innovative firms organize their purchasing function distinguishing between “advanced sourcing” and “life-cycle sourcing” unites. According to another study published by Wynstra et al. (2001) there are three issues for successful supplier involvement: identifying specific processes and tasks for broader area of purchasing involvement in product development; forming an organization that supports the execution of such tasks; and finally staffing the organization with people that have the right commercial, technical and social skills. The knowledge and specially skills of suppliers and customers should be embedded in product development process in order to be successful.

**Table 2.** Factors influencing the process of supplier integration
<table>
<thead>
<tr>
<th>Factors</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing of supplier involvement</td>
<td>Hartley et al., 1997</td>
</tr>
<tr>
<td>Suppliers’ control/monitoring</td>
<td></td>
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<tr>
<td>Degree of supplier responsibility</td>
<td>Monczka et al., 2000</td>
</tr>
<tr>
<td>Alignment of organizational objectives with regard to outcomes</td>
<td></td>
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<tr>
<td>Supplier membership on the project team</td>
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<tr>
<td>Frequency of buyer/supplier communication</td>
<td>Dröge et al., 2000</td>
</tr>
<tr>
<td>Availability of adequate human resources</td>
<td>Wynstra et al., 2001</td>
</tr>
<tr>
<td>Organization of purchasing function</td>
<td>Ragatz et al., 2002</td>
</tr>
<tr>
<td>Specific responsibilities in the requirement setting process</td>
<td></td>
</tr>
<tr>
<td>Intellectual property agreements</td>
<td></td>
</tr>
<tr>
<td>Identify managing involvement in PD</td>
<td></td>
</tr>
<tr>
<td>Trust</td>
<td>Brown &amp; Eisenhardt, 1995</td>
</tr>
</tbody>
</table>

An approach for successful integration of supplier in the product development process is the imitation of process by those companies in which they undertook a superior experience in that context and learn from their knowledge. This approach is called role modeling in psychology and has been deployed in different field of organizational development like lean implementation (Goldsby, Griffis, & Roath, 2006).

One major point in the innovation process in companies is their own definition of business strategy. The business strategy can lead innovation’s destiny and become a powerful instrument to decide for each idea at the beginning of their origin. The main question according to business strategy is the company’s own potential. We could ascend this potential by direct contribution of supplier and enhance the reliable opportunities in companies and use their possible advantages.

Brown and Eisenhardt (1995) figure out that the communication plays an important role and they suggest a communication web. The underlying premise is to ensure the communication between them and thus the stimulus performance of group. Same as Cooper’s (1990) perception, Brown and Eisenhardt (1995) determined that for an efficient result in product development there is a need of Gate-Stage-model and for each gate corresponding gatekeepers
has been defined. They are responsible for the communication outside their groups to encourage them and to ensure the resources for the group.

Heeg (2013) speaks about changing the perspective and analyze customers’ needs accurately. In order to create a common sense and support the improvement projects, Heeg recommends to set an action graph. This method enables to understand a problem in a system with its interdependencies and consider it from multiple views. The first step is collecting system elements in actual condition and defines a target condition. Under consideration of mutual reactions.

In this connection Heeg introduced his method named NELOD© as an alternative to involve external resources and ensure communication. This method allows to grasp the dynamics of changing system by identifying the relevant issues, goals, expected effects through underlying causes and reasons are illustrated in an action graph. Methods and technics like empathic communication, systematic questioning, impact analysis through other system elements and moderation which support innovation process are all included by dealing with NELOD method. This model is like a common language which ensures smooth communication between all contributed parties. One of its benefits is the decision making process which takes place in consensus of all team members (see Figure 3).

![Action graph](image)

**Figure 3.** Action graph (Heeg, 2013)

To ensure innovation management process Heeg (2009) introduced the following 8 step strategy to establish an action graph:

- Determination of system parameters;
- Intuitive Clustering of system elements;
• Defining cluster names;
• Determination of the dynamic relationship of the parties;
• Determination of the relevant levels of relations;
• Determination of the overall system dynamics;
• Determination of the feedback loops;
• Determining the ranking of the system variables and starting point for optimization.

In an empirical research conducted through Rist (2009), the improvement of organizational performance for a sample project could be measured. The main benefit was becoming innovative structures by clear definition of responsibilities and interactions.

3. The impacts of supplier involvement in product development

Aforementioned practices make it principally easy for supplier to contribute in all stages of new product development. But earlier integration of supplier is generally suggested and mentioned in literature often as the most effective solution. By involving in product development process, they receive more responsibilities and these have a direct impact on cost reduction and better quality of products. Moreover, the following adjustments are recognized earlier which ensure minimal cost, high flexibility in case of new variations (Monczka et al., 2000). Furthermore, the other impacts of supplier involvement are listed in Table 3.

Table 3. Positive impact of supplier involvement

<table>
<thead>
<tr>
<th>Possible advantages</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce product manufacturing cost and developing cost</td>
<td>Ragatz et al., 2002; Hartley et al., 1997</td>
</tr>
<tr>
<td>Improve quality and features</td>
<td>Handfield et al., 1999</td>
</tr>
<tr>
<td>Quicker response to the market changes</td>
<td></td>
</tr>
<tr>
<td>Improve reliability of overall design</td>
<td>Petersen et al., 2005</td>
</tr>
<tr>
<td>Realize the most expectation of customers</td>
<td></td>
</tr>
<tr>
<td>Decrease new product cycle time</td>
<td>Banaccorsi &amp; Lipparini, 1994;</td>
</tr>
<tr>
<td>Access to technological knowledge of suppliers</td>
<td>Bonnaccorsi, 1997</td>
</tr>
<tr>
<td>Quality and reliability of component designs</td>
<td>Wasti &amp; Liker, 1997</td>
</tr>
<tr>
<td>Alternative materials and possibilities for component designs</td>
<td>Monczka et al., 2000</td>
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</table>
We can generally categorize the benefit of supplier involvement under two aspects: Business strategy and their operational impact. Laage-Hellman (1997) distinguished four types of fit that are relevant for technological cooperation: functional fit; organizational fit; strategic fit; and time fit. However the most lauded advantages of such a cooperation with suppliers are: improving product design, cost-reduction (development or product costs), better quality, quicker response to market changes, faster completion and realize the main expectation of customer (Ragatz et al., 2002). Otherwise the companies have not only benefits from the end results in case of a cheaper product, they can profit from the new integration process and supplier experiences. We can classify the contribution of supplier with regard to design, development and engineering.

Monczka et al. (2000) described positive impact of supplier involvement as below and introduced it as Four Cs. These are Commitment to quality, Cycle-time reduction, Competitive value, and Customer satisfaction.

The benefit of cooperation between buyer and supplier can be visible in form of so-called “technology roadmaps” so that they decided for closer cooperation and new approaches together. They can be informed with the technological trends and potential of other parties and opportunities for the future contribution.

Despite the remarkable benefits of such contribution, the survey of Lehmann (2009) shows that this approach is neglected. She analyzed the companies in two regions of Germany “North Rhine-Westphalia” and “Saxony” and measured the innovation impulse which the companies received from various suppliers in both regions. The results show that depending on region and supplier affiliation, companies received roughly up to 70% of any impulse or minor impulse from suppliers in North Rhine-Westphalia. However the situation in Saxony is slightly better.

Nevertheless, in some literatures negative impact of supplier involvement in product development were found or they report a partly integration was possible. These cases will be presented in the next chapter. Eisenhardt and Tabrizi (1995) stated that involvement of supplier by product development would be faster just in developed industry segment.

4. Barrier to the involvement of suppliers in product development
Wynstra et al. (2001) took a closer look to understand the supplier involvement problems and pointed issues in dealing with the most important problems. In this case we should recognize three sides of observation: the company side, supplier side and the process between them (Wynstra et al., 2001; Wasti & Liker, 1997; Dyer & Ouchi, 1993). Few studies observe all detail of obstacle for supplier contribution providing a recommendation for manager. In Figure 4 some barriers for supplier involvement are listed.

The plenty, intensity and right time for contribution depend on different factors. In literature is impressed the grade of innovation, suppliers’ potential, intimacy and project object priority as important aspects for the depth of contribution. According to Brown and Eisenhardt (1995) it is not clear to say when and how the customer or supplier should be involved in product development. Liker et al. (1998) argues that the involvement of supplier in design has the most impact and more efficiency. He mentioned that product uncertainties impress the process of development and a firm needs to invest in developing a partnership with a selected group of supplier. For the sustainable involvement the supplier should perceive an active role, informed openly and extensively, be involved in decision making during design and finally monitoring the results and learn from experiences (Monczka et al., 2000).

Figure 4. Barrier to involve suppliers (Based on examples drawn from the following references: Wynstra et al., 2001; Monczka et al., 2000)

5. Customer involvement

Regarding the house of quality in quality function development (QFD) the customer needs are the first and the most important column. Then, right identification of their needs will be the first criterion to recognize the successful or unsuccessful products. One instrument to avoid more inaccurate decisions in case of identification of needs and in the whole development process is to integrate the customer in the NPD process. Firms can apply customers in a different section of organizations such as product development, product support and marketing. In each
section is an intensive communication mandatory to identify their conscious and hidden needs. The accurate identification of customers’ needs under consideration of their involvement has many advantages that a company can profit from them (see Table 4).

We must differ between several types of customers. We can differ between existing customers, potential customers, ordinary or lead users. The result of collaboration with average customers and innovative or lead users is very different. Von Hippel (1986) reveals that the most important customers who influence the development are so-called lead users which can be useful only in case of radical innovation. Best innovative companies try to identify lead users and work closely with them. Many commercially important products have an origin of customer contribution Von Hippel et al., 1999). On the other side the perception of Ulwick (2002) shows that customers may not have sufficient technical knowledge to help the manufacturer by NPD. Generally the more experience and knowledge a person bring, the higher is the expected quality (Gavetti, 2005).

Table 4. Impact of customer involvement

<table>
<thead>
<tr>
<th>Possible advantages</th>
<th>Literature</th>
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</thead>
<tbody>
<tr>
<td>Provide differentiated services</td>
<td>Alam, 2002; Matthing &amp; Sandén, 2004; Parahalad &amp; Ramaswamy, 2000</td>
</tr>
<tr>
<td>Reduce the development time</td>
<td>2004; Parahalad &amp; Ramaswamy, 2000</td>
</tr>
<tr>
<td>Facilitate user education</td>
<td>2000</td>
</tr>
<tr>
<td>Improve market acceptance</td>
<td></td>
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<tr>
<td>Establish a long-term relationship with customers</td>
<td></td>
</tr>
<tr>
<td>Better understand the user needs</td>
<td>Anderson &amp; Crocca, 1993; Von Hippel et al., 1999)</td>
</tr>
<tr>
<td>Improve the quality and reliability of NPD</td>
<td>Cooper &amp; Slagmulder, 2004</td>
</tr>
</tbody>
</table>

The most important question is “with whom” company should cooperate? To find an appropriate customer contribution for product development there are some methods we can generally use. We can distinguish between direct and indirect methods. Under indirect procedure we can determine complaint management, user observation and as a direct method we understand interviews/questionnaires, idea competition, focus group and lead-user methods. For example, Griffin and Hauser (1993) found that twenty one-to-one interviews with customers are enough to recognize the 90% of the customer needs.

The same as supplier contribution in new product development process, we can again recognize some barriers. The companies explained some common barriers such as: lacking of
resources, not having considered doing so and considering user idea as not producible or internal resistant.

6. Conclusions

The UK innovation survey shows that suppliers and customers are the most important external resource for co-operation despite the ambition to co-operate with supplier is slightly more than customers (Stones, 2001).

Regarding the culture as a barrier to involve both supplier and customer in product development, we must try to find a solution under this aspect in company and make them responsible for their job. More involvement means more communication and more information about the company and their processes. This occurs sometimes as an internal cultural problem in the company. The supplier must be motivated for such collaboration as well as the customer. One of the important problems for a sustainable contribution is how to allocate the revenue between the network members. They are responsible for the whole production cost, but they benefit just from the end product, which the whole parties have collaborated.

One factor is to share the benefit with the supplier. The same problem is argued for customer contribution and compared to the supplier involvement it may be more difficult. The impact of supplier involvement ideally should be linked to company level performance measures such as profit or market share.

The main difficulty is to motivate the customers’ contribution in the NPD and participate in process. Afterwards contribute by problem identification process and contribute in cross-function processes. The most critical point by customer or supplier contribution is the lack of trustfulness and knowledge. In efficient contribution form of customer literature have been spoken about lead-users (Von Hippel et al., 1999). It is necessary to review the questions: when, how and how much should be the contribution and who should decide for the next step. Otherwise the question is still to analyze: with how many customers should the technological cooperation, carry out and with which specific customer should be collaborated?

The grades of communication influenced the quality of involvement of both supplier and customer in the NPD process. Therefore, there is a need to develop methods which are promoting these factors and support the cross-functional processes. For sustainable co-operation four factors should be considered: social factors, technical factors, legal factors and economic factors. On the other side, enterprise must evaluate the external contributions under consideration of cost and quality. By gathering information over all these factors decision over suitable supplier could be made. Further research could analyze and develop an instrument to
support enterprises in this context. However, general challenges are still remained mainly by initiation of this practice like, selection of right supplier or customer, knowledge about their effectiveness and efficiencies by radical innovations and more over dealing difficulties with sensible firms.

We conclude that for innovation management in collaboration of other parties, one standard procedure should be employed. This procedure insures the communication between team members and collecting customer requirements and integration in a multi-project management support the transformation. Therefore, Heeg (2009) recommends supplier or customer integration with the assist of system theory.

Finally, five stages of supplier partnership development could be defined: Give supplier an active role, define clear strategy and targets, share information openly and extensively, active involvement of suppliers in decision making and problem solving during design, and Monitor results and learn from experience (Monczka et al., 2000). These issues are mainly part of organizational development.

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References


