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CRITICAL OPERATIONS CAPABILITIES IN A HIGH COST ENVIRONMENT: A GREY RELATIONAL ANALYSIS

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Abstract:
Operations capabilities has been a common research area for many years and several frameworks have been offered. The existing frameworks are general and do not take specific contexts into consideration, such as a high cost environment. This research gap is of interest as a manufacturing relocation process has been taking place during the last decades, resulting in a vast amount of manufacturing being moved from high to low cost environments. The purpose of this study is to analyse critical operations capabilities in a high cost environment. A survey study was conducted, which focused on the evaluation of an existing framework of operations capabilities in the specific high cost environment context. Data was collected by a questionnaire that was developed based on the existing framework and distributed to 14 managers in five Swedish manufacturing firms. Grey relational analysis (GRA) was used to rank and cluster the dimensions and operations capabilities. The findings revealed that all the dimensions and operations capabilities included in the framework were critical in a high cost environment. However, the analysis also indicated that different emphasis was put on the different dimensions and capabilities. Thus, the dimensions and capabilities were ranked in order of critically and clustered as either 'most critical', 'critical', or 'least critical'. The most critical dimension was 'quality' while the least critical dimension was 'environment'. The critical dimensions included 'delivery', 'cost', 'flexibility', 'service' and 'innovation'. The findings increased the validity of the framework and its usefulness in a high cost environment.

Keywords: operations strategy, priority, capability, high cost environment, grey relational analysis, Sweden

1. INTRODUCTION

In order to maintain a long term competitive advantage, firms need to focus on operations strategy, develop operations capabilities (Größler & Grübner, 2006) and achieve highest levels of performance on dimensions such as quality, flexibility, delivery and cost (Sarmiento et al., 2007; Hilmola et al., 2015). Moreover, the developed operations capabilities need to be aligned with the market requirements (Ho, 1996) and manufacturing context.

The research area of operations strategy and capabilities has a high popularity. Several frameworks of operations capabilities have been proposed in the literature (e.g., Frohlich & Dixon, 2001; Miller & Roth, 1994). However, the existing frameworks are general and do not take specific manufacturing contexts into consideration, such as a high cost environment. This research gap is of particular interest as a manufacturing relocation process has been ongoing in the last decades (Jensen & Pedersen, 2012), resulting in an extensive movement of manufacturing to low cost environments. Therefore, it is important to analyse which are the critical operations capabilities for manufacturing in a high cost environment (Sansone & Hilletofth, 2016).

The purpose of this study is to analyse critical operations capabilities in a high cost environment. In order to satisfy this purpose, the following research questions were formulated: (1) 'Which are the critical *dimensions* in a high cost environment?', and (2) 'Which are the critical operations *capabilities* in a high cost environment?' These questions were targeted through a survey study focused on the evaluation of an existing framework of operations capabilities (Sansone et al., 2017) in the specific high cost environment context. Data was collected through a questionnaire that was distributed to 14 managers in five Swedish manufacturing firms and the collected data was analysed through grey relational analysis (GRA).

The remainder of this paper is structured as follows: Section 2 forms the theoretical framework and includes the introduction and discussion of a recent framework of operations capabilities (Sansone et al., 2017). Section 3 discusses this study's design and includes all the information regarding the research process and the procedure in which the study was conducted. Thereafter, in Section 4, the framework that proposes operations dimensions and capabilities is evaluated with the use of GRA based on the collected empirical data. The criticality level of the operations dimensions and their capabilities in a high cost environment is discussed. Finally, the research is concluded and suggestions for further research are given in Section 5.

2. THEORETICAL FRAMEWORK

Sansone et al. (2017) propose a framework of operations capabilities, which can be used as a strategic starting point for manufacturing firms (Table 1). The framework was developed based on a systematic literature review of more than 157 papers and it is an extension of previous frameworks (e.g., Miller & Roth, 1994; Frohlich & Dixon, 2001).

In the literature there is an agreement on four basic dimensions (Hallgren, 2007):

1. **Cost** represents the manufacturing firm's ability to generate profits by offering products at the lowest price (Alsmadi et al., 2011) and optimize the utilization of manufacturing resources (Sansone et al., 2017);
2. **Quality** represents the manufacturing firm's ability to provide high performance products and processes that correspond to specifications and that withstand hard use over an extended period of time (Zhao et al., 2002);
3. **Delivery** represents the manufacturing firm's ability to deliver products to the customer (Corbett & Claridge, 2002);
4. **Flexibility** represents the manufacturing firm´s ability to: change production volume and range of products, to customize the product and to offer a wide range of products (Sansone et al., 2017).

Some additional dimensions are discussed in the literature but there is still not an agreement on whether they should be considered basic ones (Hallgren, 2007) and therefore they are not always included in previous frameworks (e.g., Frohlich & Dixon, 2001; Miller & Roth, 1994):

5. **Service** represents the manufacturing firm´s ability to offer a good service to the customer (Bolivar Cruz & Espino Rodriguez, 2008) and to promote the product and make it easily available to the customer (Sansone et al., 2017).

6. **Innovation** represents the manufacturing firm´s ability to develop new products, new technologies, new service and create or expand new markets (Sansone et al., 2017).
7. **Environment** represents the manufacturing firm´s ability to produce environmental friendly products through environmental friendly processes (Sansone et al., 2017).

Table 1: Framework of operations capabilities (Sansone et al., 2017)

Dimension	Capability	Definition
Cost	Total cost	Ability to reduce production and distribution costs.
	Productivity	Ability to optimize the utilization of manufacturing resources (machines, equipment, and labour) and increase their output.
Quality	Performance	Ability to provide products and processes operating at a desired and high level of performance.
	Conformance	Ability to offer products and manufacturing processes that correspond to the specifications, which help to guarantee defects free products.
	Durability	Ability to offer durable products that withstand hard use over an extended period of time.
Delivery	Dependability	Ability to provide reliable delivery by meeting delivery schedules or promises.
	Speed	Ability to provide fast delivery and respond quickly to customer's order.
Flexibility	Volume flexibility	Ability to change production volume and respond rapidly to volume change.
	Production mix flexibility	Ability to change the range of products in the production and respond rapidly to changes.
	Customization flexibility	Ability to adjust the product based on the customer's requirements and needs.
	Broad product line	Ability to offer a wide range of products, with a large number of features.
Service	Customer service	Ability to add value to the product by providing product information and making the product easily available and obtainable.
	After sale service	Ability to add value to the product after the purchasing by providing effective after sale services, and delivering appropriate technical assistance and product support.
	Advertising	Ability to market, promote the product, and improve the company's image.
	Broad distribution	Ability to make the product available to a larger group of customers.
Innovation	New product	Ability to develop and introduce updated or novel products to the market.
	New technology	Ability to develop and implement updated and novel technologies.
	New service	Ability to develop and present updated and novel services to the customers.
	New market	Ability to create, expand and develop products and services, as to reach a specific group of customers.
Environment	Products	Ability to produce products with a reduced or positive environmental impact.
	Processes	Ability to have processes with a reduced or positive environmental impact.

The framework adopted in this study includes all of these seven dimensions. Each dimension comprises two or more specific operations capabilities. In total, 21 operations capabilities are included in the framework. The framework with all the capabilities definitions is found in Table 1.

3. RESEARCH DESIGN

The purpose of this study is to analyse critical operations capabilities in a high cost environment. To fulfil this purpose a survey study was conducted, which focused on the evaluation of an existing framework of operations capabilities (Table 1) in the specific high cost environment context. A questionnaire was distributed to 14 managers from five Swedish manufacturing firms and included 21 rating questions in total, which were related to the 21 operations capabilities included in the existing framework.

The respondents were asked to grade each questionnaire item on a Likert-scale from one to five (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). The higher the score, the more emphasis the respondents put on the operations capability and vice versa. The collected data was analysed with GRA, an impact evaluation model that measures the degree of similarity, or difference between two sequences and is based on the grade of relation (Deng, 1986).

GRA contains four steps that needed to be completed in order to analyse Likert-scale surveys (Chan & Tong, 2007): (1) preparation of factor compatibility, (2) derivation of reference sequences, (3) calculation of grey relational coefficient, and (4) determination of grey relational grade. When calculating the GRA, a multi-criteria problem needed to be formulated by using a set of alternatives $(x_1, x_2, \ldots, x_{13})$, in this study the operations capabilities, and criteria $(k_1, k_2, \ldots, k_5)$, which represent the Likert-style rating scale. Each criterion was assigned weightings and a preference index (PI). If a higher number of respondents choosing the value of each *k* will have a positive impact on *x*, the PI is equal to one. Otherwise, it is equal to zero.

The main decision that was needed to be made concerned whether the PI of each *k* is one or zero. Since k_1 and k_2 represent the Likert-style rating scales that indicate that respondents deem the corresponding capability is 'neither critical nor important for success' or 'important but not critical/necessary for success', their PI is equal to zero. However, the PI of k_3 requires more thought, as it divides the options that represent a positive or negative outcome for *x*. In this study, the decision is made that k_3, which represents the median Likert-style rating scale outcome 'somewhat critical and important for success' is also equal to zero, as it not clearly indicates a positive outcome for *x*. k_4 and k_5 are equal to one, since they represent the Likert-style rating scales 'critical and important for success' and 'extremely critical and important for success', which clearly indicate a positive outcome for *x*.
The first step was to formulate the following decision matrix D:

$$D = \begin{Bmatrix} x_1(k_1) & \ldots & x_i(k_1) & \ldots & x_m(k_1) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_1(k_j) & \ldots & x_i(k_j) & \ldots & x_m(k_j) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_1(k_n) & \ldots & x_i(k_n) & \ldots & x_m(k_n) \end{Bmatrix} \quad (1)$$

where:

$$\mathrm{PI}_j = \begin{cases} 1, & \text{Increasing} \\ 0, & \text{Decreasing} \end{cases} \quad (2)$$

After normalization, it was turned into matrix D':

$$D' = \begin{Bmatrix} x_1(k_1)' & \ldots & x_i(k_1)' & \ldots & x_m(k_1) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_1(k_j)' & \ldots & x_i(k_j)' & \ldots & x_m(k_j)' \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_1(k_n)' & \ldots & x_i(k_n)' & \ldots & x_m(k_n)' \end{Bmatrix} \quad (3)$$

where:

$$x_i(k_j)' = \frac{x_i(k_j) - \min_{\forall j}\left\{x_{i(k_j)}\right\}}{\max_{\forall j}\left\{x_{i(k_j)}\right\} - \min_{\forall j}\left\{x_{i(k_j)}\right\}} \quad (4)$$

Then, a pre-reference sequence $y_0 = \left\{y_{0\,(k_j)}; k = 1, 2, 3, \ldots, m\right\}$ was determined:

$$y_0(k_j) = \begin{cases} \min_{\forall i}\left\{x_{i(k_j)}\right\} & \text{if } \mathrm{PI}_J = 0 \\ \max_{\forall i}\left\{x_{i(k_j)}\right\} & \text{if } \mathrm{PI}_J = 1 \end{cases} \quad (5)$$

The reference sequence $y'_0 = \left\{y_{0\,(k_j)}'\right\}; k = 1, 2, 3, \ldots, m$ was computed by turning all decreasing criteria into opposite direction:

$$y_0(k_j)' = \begin{cases} 1 - y_{0(k_j)} & \text{if } \mathrm{PI}_J = 0 \\ y_{0(k_j)} & \text{if } \mathrm{PI}_J = 1 \end{cases} \quad (6)$$

Finally, each sequence was compared with the reference sequence by calculating the grey relational coefficient:

$$y\left(y_0(k), x_i(k)\right) = \frac{\Delta \min + \zeta\Delta \max}{\Delta_{oj}(k) + \zeta\Delta max} \tag{7}$$

ζ served as the equation's contrast control and the value of 0,5 was applied (Deng, 1986). After the grey relational coefficient was obtained, the mean of this coefficient can be used as the grey relational grade:

$$y(y_0, x_i) = \frac{1}{n}\sum_{j=1}^{n} y\left(y_0(k), x_j(k)\right) \tag{8}$$

To consider the unequal weights among the factors, the formula above needed to be extended to define the grey relational grade:

$$y(y_0, x_i) = \frac{1}{n}\sum_{j=1}^{n} \beta_k y\left(y_0(k), x_j(k)\right) \tag{9}$$

Within this formula, β_k determined the normalized weight of criterion *k*, where $\sum_{k=1}^{n} \beta_k = 1$ and with equal weights. Since this study's chosen Likert-style rating scale consists of five fixed choice response formats, each *k* had a normalized weight of 0,2.

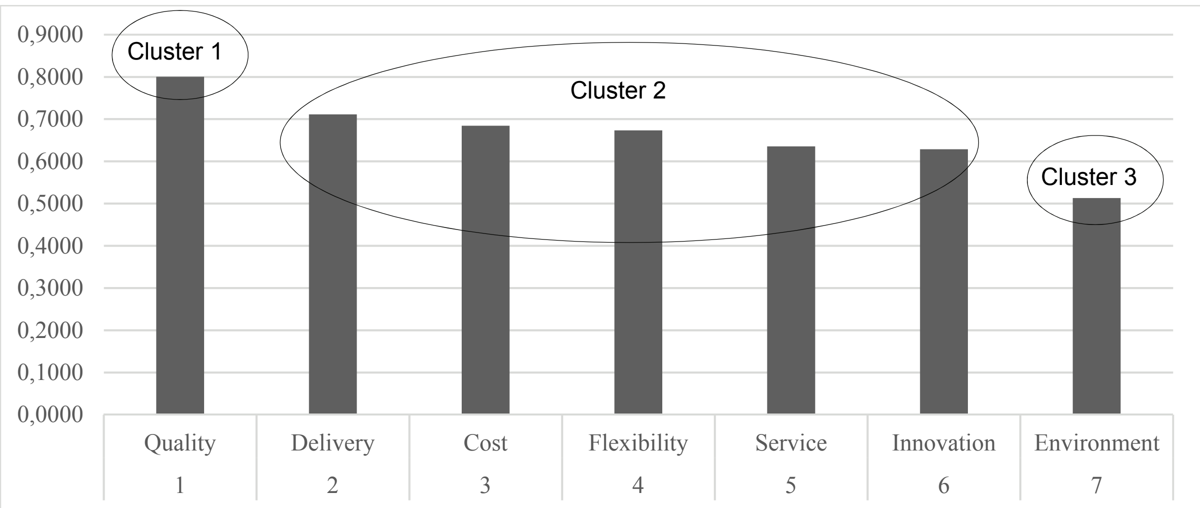
4. FINDINGS AND ANALYSIS

In order to evaluate the critical operations capabilities in a high cost environment, a questionnaire was distributed to 14 managers in five Swedish manufacturing firms. The outcome was processed with GRA, enabling the identification of the criticality level of the proposed dimensions and operations capabilities in a high cost environment. Thereafter, the dimensions and operations capabilities were clustered based on their level of criticality.

4.1. Dimension level analysis

The results presented in Picture 1 show that each dimension has a mean GRA value equal or higher than ζ 0,5. Thus, it may be argued that all of the proposed dimensions were considered to be critical in a high cost environment. However, different emphasis was put on each dimension, which enabled ranking the dimensions in order of criticality. As can be seen in Picture 1, the dimensions were also arranged into clusters based on their GRA value. Clustering enabled the labelling of the dimensions as either 'most critical', 'critical', or 'least critical'.

Picture 1: Ranking and clustering of the operations dimensions



The dimension 'quality' has a mean GRA value of 0,8004 (Picture 1). This dimension forms the first cluster and it is identified as 'most critical' in a high cost environment. The dimension means that firms have to pay sufficient attention to quality in order to avoid losing customers and profits (Zhao et al., 2002), as quality is becoming increasingly important in today's global competition (Alsmadi et al., 2011).

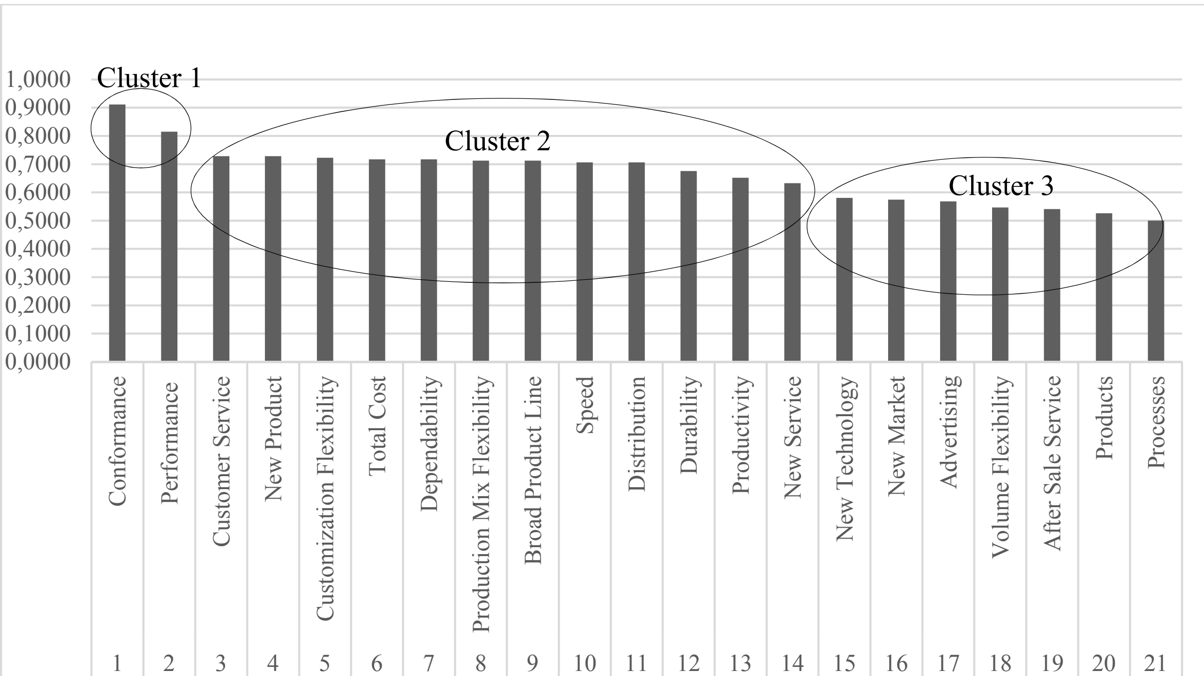
The dimensions 'delivery', 'cost', 'flexibility', 'service', and 'innovation' have a mean GRA value between 0,7113 and 0,6287 (Picture 1). These dimensions form the second cluster and they are identified as 'critical' in a high cost environment. These dimensions mean that firms have to: prioritize the ability to deliver product to the customer (Corbett & Claridge, 2002); be highly conscious of cost control (Zhao et al., 2002); be flexible to adapt to the increasing market dynamism (Größler & Grübner, 2006); offer good services to win the competition (Bolivar Cruz & Espino Rodriguez, 2008); and be highly conscious of innovation as a source of sustainable economic growth.

The dimension 'environment' has a mean GRA value of 0,5130 (Picture 1). This dimension forms the third cluster and it is identified as 'least critical' in a high cost environment. This dimension means that firms need to recognize environmental aspects as a critical variable for success (Da Silva et al., 2009).

4.2. Capability level analysis

The results presented in Picture 2 show that each operations capability has a GRA value equal or higher than ζ 0,5. Thus, it may be argued that all of the proposed capabilities were considered to be critical in a high cost environment. However, different emphasis was put on each capability, which enabled ranking the capabilities in order of criticality. As can be seen in Picture 2, the capabilities were also arranged into clusters based on their GRA value. Clustering enabled the labelling of the capabilities as either 'most critical', 'critical', or 'least critical'.

Picture 2: Ranking and clustering of the operations capabilities



The operations capabilities 'conformance' and 'performance' have a GRA value of 0,9111 and 0,8147 (Picture 2). These capabilities form the first cluster and they are identified as 'most critical' in a high cost environment. These capabilities mean that firms need to offer a product that is conformed to the design specifications and focus on the ability of providing high performance products (Nair & Boulton, 2008).

The operations capabilities 'customer service', 'new product', 'customization flexibility', 'total cost', 'dependability', 'production mix flexibility', 'broad product line', 'speed', 'distribution', 'durability', 'productivity', and 'new service' have a GRA value between 0,7281 and 0,6322 (Picture 2). These capabilities form the second cluster and they are identified as 'critical' in a high cost environment. These capabilities mean that firms need to: focus on the proper treatment of customers (Bolivar Cruz & Espino Rodriguez, 2008); try to compete through innovation with new products (Krause et al., 2001); offer customize products (Dangayach & Deshmukh, 2001); reduce total production cost (Avella et al., 2001); deliver according to promised schedule (Chi, 2010); produce a mix of products; have a broad product line; have fast delivery (Chi, 2010); distribute the products broadly; offer durable products (Nair & Bolton, 2008); increase productivity; and create new services for customers.

The operations capabilities ‘new technology’, ‘new market’, ‘advertising’, ‘volume flexibility’, ‘after sale service’, ‘products’, and ‘processes’ have a GRA value between 0,5805 and 0,5000 (Picture 2). These capabilities form the third cluster and they are identified as ‘least critical’ in a high cost environment. These capabilities mean that firms need to: use new technologies; acquire new markets (Zhao et al., 2002); promote their products; handle volume changes (Zhao et al., 2002); offer after sale services; offer environmental friendly products (Longoni & Cagliano, 2015).

5. CONCLUSIONS

This study aimed to analyse critical operations capabilities in a high cost environment. To fulfil this purpose, the following research questions needed to be answered: (1) ‘Which are the critical *dimensions* in a high cost environment?’, and (2) ‘Which are the critical operations capabilities in a high cost environment?’. A survey study was conducted which focused on the evaluation of an existing framework of operations capabilities in the specific high cost environment context. Data was collected through a questionnaire that was distributed to 14 managers in five Swedish manufacturing firms and the collected data was analysed through GRA.

The findings revealed that all the dimensions (7) and capabilities (21) included in the framework were critical in a high cost environment. However, the analysis also indicated that different emphasis was put on the different dimensions and capabilities. Therefore, the dimensions and capabilities were ranked in order of criticality and clustered as either ‘most critical’, ‘critical’, or ‘least critical’, based on their GRA value (Picture 1 & 2). Concerning the first research question, the analysis identified that the most critical dimension was ‘quality’ while the least critical dimension was ‘environment’. The critical dimensions were ‘delivery’, ‘cost’, ‘flexibility’, ‘service’ and ‘innovation’. Concerning the second research question, the most critical capabilities were ‘conformance’ and ‘performance’ while the least critical were: ‘new technology’ and ‘new market’ included in the ‘innovation’ dimension; ‘advertising’ and ‘after sale service’ included in ‘service’ dimension; ‘volume flexibility’ included in the ‘flexibility’ dimension, ‘products’, and ‘processes’ included in the ‘environment’ dimension. Manufacturing firms involved in this study emphasized the criticality of quality as a way to win the competition and avoiding losing customers and profits (Zhao et al., 2002). This is reflected on a prioritization of capabilities like: the ability of offering quality products conformed with the specifications and the ability to provide products at a high level of performance.

Due to the manufacturing relocation process that has been ongoing during the last decades (Jensen & Pedersen, 2012), it is important to analyse critical operations capabilities for competitive manufacturing in a high cost environment. The latter is a niche that has been neglected in the literature, and thereby this study delivers additional value by analysing critical operations dimensions and capabilities when composing an operations strategy in this specific context. The dimensions and capabilities analysed in this study are critical and affect the competitiveness and the future outlook of manufacturing firms in a high cost environment. This paper is a step towards defining guidelines when practitioners compose a winning operations strategy.

Since this study is limited to 14 managers from five Swedish manufacturing firms, future research must consider more, and also different types of, managers and companies in the Swedish manufacturing industry. Another improvement would to be to compare different types of high cost environments. Later on it is also necessary to conduct the same type of study in a low cost environment in order to identify similarities and differences between these two types of manufacturing contexts.

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