FEASIBILITY OF ANALYTICAL HIERARCHY PROCESS AS A TOOL FOR RESHORING DECISIONS

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ABSTRACT
Reshoring decision making is least explored as these decisions are complex and time-consuming. Numerous quantitative and qualitative criteria need to be considered in the decision-making. The existing decision-making tools are few and theoretical and lack automatic decision support capabilities. Therefore, there is a need of automatic and rapid decision support tool for reshoring decision making. One of the more well-known systematic decision-making tools is analytical hierarchy process (AHP) that has been used to handle complex decision problems in operations management domain. This study aims to investigate the feasibility of AHP as a tool for reshoring decision-making. In order to achieve this, the AHP was applied to six reshoring criteria on an overall level, which also correspond to competitive priorities. First, a hierarchy of criteria was constructed, then the pairwise comparison of each criteria pair was made, then the final priority weights of the criteria were calculated, and finally the consistency of the comparisons was checked. The criteria Quality and Cost obtained higher priority weights in reshoring decision. Later, the final priority weights of the criteria were used to evaluate fifteen different reshoring decision scenarios and compared against reshoring expert's opinion. It was found that thirteen of these decision evaluations were correct on comparing the AHP outputs and the expert's opinion. Only two of the evaluations were not in agreement, however the confidence values on these decisions were very small. Therefore, this research shows that AHP is a feasible tool for reshoring decision making on an overall level of criteria. The tool can be adapted to different decision makers and different reshoring types. The tool provides automatic support for reshoring decisions.

Keywords: Reshoring decision making, AHP, Decision support tool, Manufacturing location.

1. INTRODUCTION

Over the past three decades, increasing globalization has resulted in an offshoring of manufacturing activities from high-cost to low-cost countries (Ketokivi et al, 2017; Schmeisser, 2013). The offshoring has been mostly a cost-based decision where companies have tried to exploit the cost advantages from low-cost countries, particularly low labor costs resulting in reduced manufacturing cost. (Ellram et al, 2013; Gylling et al, 2015; Theyel et al, 2018). The cost-based decision has been argued to have considered too little or erroneous information not covering holistic set of factors that should have been included while making a location decision (Eriksson et al, 2018). Recently, there is increasing literature that sheds light on the down sides of offshoring, and that both quantitative and qualitative factors that needs to be considered (Holweg et al, 2011; Tate, 2014; Stanczyk et al, 2017). The failure to correctly assess offshoring, along with rapidly changing global trends, have sparked an academic discussion for reshoring- to move manufacturing back to the country of origin (Gray et al, 2013; Fratocchi et al, 2014) or nearshoring- move manufacturing to a close-by country (Slepniov et al, 2013; Panova & Hilletofth, 2017).

Manufacturing reshoring decisions are complex due to a large number of criteria and multiple stages involved making them time and resource consuming to process these criteria (Stentoft et al, 2018). The most common groups of criteria to consider in a decision have been well explored and can be divided into cost-related criteria, such as labor cost and monitoring cost (Engström et al, 2018a; Engström et al, 2018b; Di Mauro et al, 2018), quality-related criteria, such as product quality and process quality (Arlbjørn & Mikkelsen, 2014; Stentoft et al, 2016; Johansson & Olhager, 2018), market-related criteria, such as global economy (Kinkel & Maloca, 2009; Kinkel, 2012), strategy-related criteria, such as firm's own manufacturing strategy (Baraldi et al, 2018) and risk-related criteria, such as natural disasters and intellectual property risk (Ellram et al, 2013; Tate et al, 2014). Quantitative decision-making tools such as lowest-per-unit-landed- cost have not been able to successfully implement qualitative criteria, and more thorough heuristics is suggested (Gray et al, 2017).

The most advanced decision model in the reshoring literature is the system dynamics model (Gray et al, 2017). However, the model still does not account for the less obvious costs and ignores the less quantifiable variables (Barbieri et al, 2018). A further progress has been made recently in reshoring decision making by applying linguistic tools in the form of fuzzy logic so that the criteria can be expressed in qualitative terms and a reshoring decision is made (Hilletofth et al, 2019). However, such decision support tools are still in their early stages of development and requires a large amount of training data. The existing decision models for reshoring are generic; and divides between the actual decision-making process and the reshoring implementation process (Boffelli et al, 2018). However, due to its complexity, there are no clear boundaries between decision-making and implementation processes.

One kind of decision support tool is the analytical hierarchy process (AHP) which has been widely been applied to tackle less quantifiable variables in operations management problems (Vaidya & Kumar, 2006). The AHP stems from applied mathematics and operations research domains that prefers to quantify judgements of the decision maker in order to make resilient decisions (Brunelli, 2015). It provides a way to structure qualitative and quantitative criteria in a systematic manner and simple way to solve decision making problem (Saaty, 1980). For reshoring decisions as well, managers rely on their experience and understanding of the firm's internationalization process (Gray et al, 2017). The purpose of this study is to investigate the feasibility of AHP for reshoring decision-making.

The remainder of the paper is structured as follows. To begin with, a brief overview of AHP process and its main parts are presented in Section 2. Thereafter, related works of AHP applications are presented in Section 3. After that, the AHP for reshoring decision making application is conceived and described in Section 4. Thereafter, the results from the AHP are presented for different reshoring scenarios and discussed in Section 5 and 6 respectively. Finally, the research is concluded in Section 7.

2. THE AHP PROCESS

The analytical hierarchy process (AHP) is both a theory and methodology that involves relative measurement (Brunelli, 2015). This means that the decision maker is not interested in exact measurement of a criterion, but only the ratio of one criterion over the other. Due to the subjectivity of comparisons, it can be argued that AHP belongs to category of 'soft' operations research, however when AHP was revisited it became clearer to researchers that it belonged to 'hard' operations research (Mingers, 2011; Brunelli, 2015). The AHP is applied to decision making problems that consists of one goal and finite number of alternatives. The goal is reached by evaluating various decision criteria and sub-criteria. The criteria and sub-criteria are the characteristics of making one alternative preferable over the other. Often a large number of criteria or sub-criteria increases the complexity of the decision (Brunelli, 2015). The criteria and sub-criteria are then expressed as weights or a ratio of importance on an overall level. There have been several methods to obtain the weights which is elucidated in the literature such as priority vector method (Saaty, 1980), Eigenvector method (Crawford & Williams, 1985) and geometric mean method (Choo & Wedley, 2004).

The AHP procedure consists of three main steps: hierarchy construction, pairwise priority analysis and consistency validation (Figure 1). In the first step (i.e., hierarchy construction), the decision-makers structure a complex problem consisting of numerous quantitative and qualitative criteria in the form of a simple hierarchy (Saaty, 1980; Vaidya & Kumar, 2006).

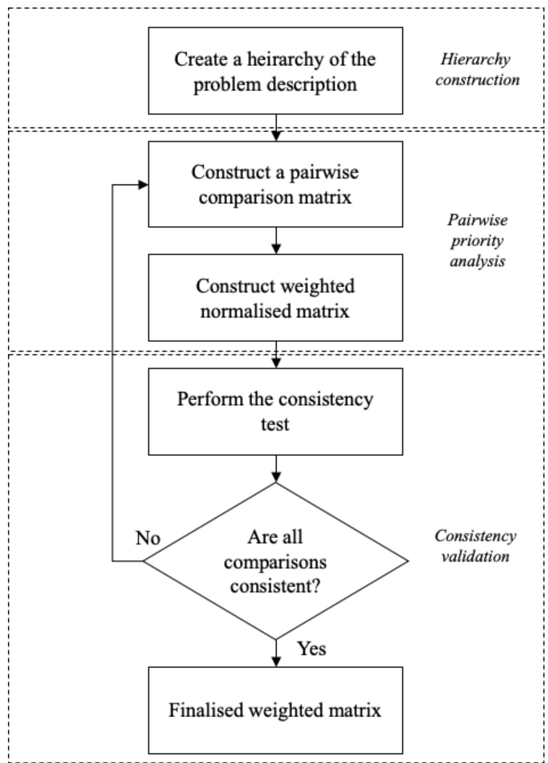

Figure 1. The AHP process (adapted from Ho et al, 2006)

At the top of the hierarchy, the problem objective is specified, and on subsequent levels, the criteria and sub-criteria are organized. The hierarchy establishes interrelationships between various criteria and sub-criteria. At the lowest level, the decision alternatives are specified. In the second step (i.e., pairwise priority analysis), the decision makers compare each criterion in the same level in a pairwise manner to every other criterion, based on their previous knowledge and experience (Schoenherr et al, 2008). For instance, two criteria on the second level are compared at a time, with respect to the goal on the first level, whereas every two sub-criteria on the third level are compared at a time with respect to the corresponding criterion on the second level. These comparisons are mostly subjective judgements. In the third and final step, (i.e., consistency validation) a consistency ratio of the pairwise comparisons is calculated. The consistency ratio acts as a thermometer for decision makers to ensure that their pairwise comparisons are consistent (Brunelli, 2015). If the consistency ratio is greater than a 0.1, then the decision-makers need to revise the comparisons made in the second part of the process (Wang et al, 2004).

3. RELATED WORKS

The AHP has been used to handle different kinds of unstructured problems in domains of economics, education, industry, management, manufacturing, government, personal, political, sports and social sciences (Vaidya & Kumar, 2006; Ho et al, 2008). The kinds of the problems handled by AHP can be broadly divided into selection, evaluation, benefit-cost analysis, priority and ranking, decision making and forecasting (Vaidya & Kumar, 2006). Out of these, the most common kind of problem is selection and evaluation. Within the field of operations management, the applications of AHP has been classified into several themes such as operations strategy, process/product design, planning and scheduling resources, project management and supply chain management (Subramanian & Ramanathan, 2012). Among them, the theme interesting for reshoring research is supply chain management. Within this theme the applications of AHP are divided into topics supplier selection, location decisions and outsourcing decisions (Subramanian & Ramanathan, 2012).

Within supplier selection, the AHP remains the most commonly used technique (Chai et al, 2013). One study applied the AHP method to find the most sustainable supplier (Luthra et al, 2017). Several sustainable supplier selection criteria were evaluated, and the method was applied in a single case study in an automobile context. The criteria were divided according to the sustainability pillars: economic, environment and social. The result was a ranking of alternatives of five potential suppliers. Another study applied the AHP to evaluate product related characteristics for supplier selection (Wang et al, 2004). The supply chain operations reference (SCOR) model was used to generate the performance metrics. Then integrated AHP and goal programming was used to consider both qualitative and quantitative factors for supply selection. The result was a selection of the most lean, agile and hybrid supplier out of the nine alternative suppliers. Another study applied AHP method for supplier selection in the automotive industry (Dweiri et al, 2016). The criteria were price, quality delivery and service. Based on the criteria several sub criteria under these were evaluated. The final result was selection of the supplier based on sub criteria. The study also performed a sensitivity analysis regarding how the changes in criteria evaluation could change the ranking of the suppliers.

Within location decision, AHP has been applied to select the optimum facility out of known alternatives. One such study applied AHP to select plant location in a logistics network based on both quantitative and qualitative factors (Chang & Lin, 2015). The criteria considered were cost, labor, supply chain, environment, customs and performance. The criteria were obtained from an in- depth single case study. Out of these, the cost and the performance had the highest weight in the decision. The result was the selection of an optimal plant location out of three alternatives. Another study applied AHP to select the collection center in case of reverse logistics in the supply chain (Kannan et al, 2008). The criteria that were proposed and considered were cost, time to market, collection center, transportation, and product. Similarly, in this study, cost had the highest weight in the decision. The result was the selection of the best collection center out of three potential alternatives. Another study applied AHP to evaluate the best location for facility (Chuang, 2001). The criteria related to location requirements were set-up and operating costs, transportation infrastructure, IT infrastructure, proximity to suppliers and market, political conditions, labor conditions, land, energy and working environment. Also, in this study, set-up and operating costs had the highest weight. The result is the evaluation of three of the candidate locations.

Within outsourcing decision, AHP has been applied to evaluate and make an outsourcing decision. One study provides decision support for outsourcing in a manufacturing company (Schoenherr et al, 2008). The criteria were 17 supply chain risk factors that were identified in a single case study. These were divided into three groups: people, partner and environment. The criteria with the highest weight was product cost. Five sourcing alternatives were assessed. The result from AHP showed that sourcing finished goods from China was the most preferred alternative. Another study has explored hybrid modelling techniques such as particle swarm optimization (PSO) to optimize the weights in AHP process in outsourcing (Li et al, 2018). The criteria considered were quality, price, time, reliability and availability of outsourced suppliers. Multiple objective functions were defined for each criterion and implemented in model. The model is iterative and evaluatesthe best outsourcing option out of ten alternatives. The study makes a comparison with other hybrid modelling techniques and argues that PSO has better stability and convergence (Li et al, 2018).

4. AHP TO RESHORING DECISION MAKING

In order to apply AHP to reshoring decision making, the criteria for reshoring are first defined. The criteria emerge from literature reviews on reshoring drivers, enablers and barriers (Barbieri et al, 2018; Wiesmann et al, 2017). In total , six high-level criteria corresponding to competitive priorities in the broader operations management domain were since the main goal of any relocation decision is to increase competitiveness (Hilletofth et al, 2019; Sansone et al, 2017). The six high-level reshoring criteria are: cost, quality, time, flexibility, innovation and sustainability (Hilletofth et al, 2019) and the same can also be applied to any relocation decision.

In the first step, decision-makers structure a reshoring problem consisting of six main criteria in the form of a hierarchy (Figure 2). Few studies have been able to establish hierarchical relationships among the reshoring criteria (e.g., Sequeira & Hilletofth, 2019). The objective of the AHP problem is reshoring decision and therefore forms the first level. On the next level, there are the six main reshoring criteria. The bottom-most and fourth level consists of the decision alternatives, and in this study only two alternatives are considered: Evaluate reshoring and Do not evaluate reshoring. Evaluate reshoring is when the decision maker should process with complete evaluation, and Do not evaluate reshoring is when a complete evaluation is not required at the moment. Since this study only looks at the feasibility of the tool, it is possible in future to extend the set of alternatives; for example, evaluate reshore-insource and evaluate reshore-outsource.

The first reshoring criterion is Cost. Most reshoring decisions are taken on the basis on cost comparison from total landed cost and total cost of sourcing models (Gylling et al, 2015; Denning, 2013). Many costs during previous offshoirng have hidden or greater than expected and this can favor one location over the other (Benstead et al, 2017). Such costs need to be identified in order to incorporate them in AHP (Sequeira & Hilletofth, 2019). The next reshoring criterion is Quality. Some studies have shown that the offshoring of manufacturing, particularly in the fashion industry has caused problems of quality defects in the products that threatened the integrity of the brand (Ashby, 2016; Robinson & Hseih, 2016; Di Mauro et al, 2018). The quality criterion addresses the firm's ability to increase the quality of the products, services and its operations. The next reshoring criterion is Time. Studies have shown that time-related criteria such as reduced lead time and time to market have been important issues for moving product back (Martinez-Mora & Merino, 2014; Stentoft et al, 2016). This criterion addresses the firm's ability to speed up its operations. The next reshoring criterion is Flexibility, which represents the firm's ability to be make changes in its operations. Studies from SMEs context have shown that firms have considered flexibility aspects such as to respond to changes in demand and customization (Ancarani & Di Mauro, 2018; Gray et al, 2017). The next reshoring criterion is Innovation, and this represents the firm's ability to be innovative in its operations. Some studies have shown reshoring firms have considered product and process innovation as an important factor (Moradlou & Tate, 2018; Fratocchi et al, 2018), The last reshoring criterion is Sustainability, and this represents the firm's ability to be sustainable in its operations. Some studies have explored sustainability factors that have caused firms to create shorter and local supply chain (Ashby, 2016; Uluskan et al, 2017).

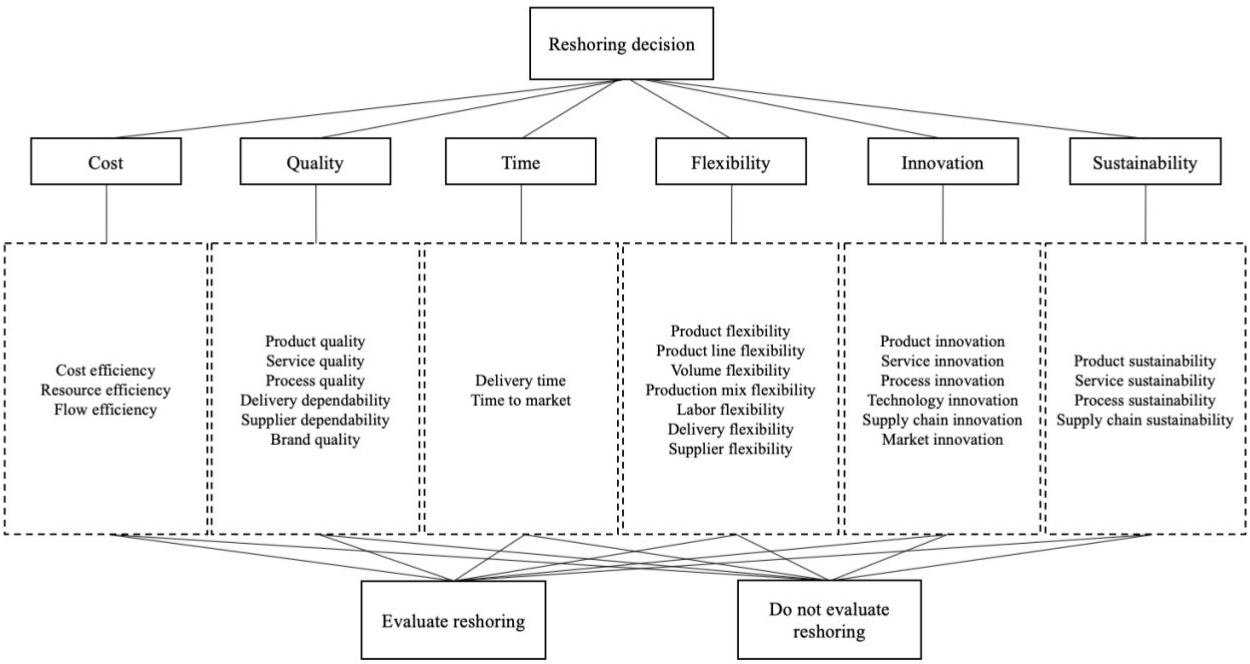

Figure 2. The hierarchy of reshoring decision making

In the second step, the decision makers compare each criterion in the same level in a pairwise manner to every other criterion, based on their previous knowledge and experience. The pairwise comparison was done in collaboration with domain experts, who have experience in reshoring decision making. In order to keep the study simple and only check the feasibility of the study, the comparison was only done on a main criteria level that includes the six criteria. The pairwise comparison is done on a nine-point scale (Table 1), that resembles the decision makers preference of one criterion over the other (Saaty, 1980). These are based on expert's judgements and are expressed as integers (Routroy & Pradhan, 2013). For example, if Quality is moderately preferred over Cost, then the value 3 is entered in row Quality and column Cost. Also, for example, if Time is equally preferred as Flexibility then, the value 1 is entered in both places.

Table 1. Pair-wise comparison scale for AHP comparison

Numerical rating	Verbal meaning of the rating
9	Extremely preferred
7	Very strongly preferred
5	Strongly preferred
3	Moderately preferred

1	Equally preferred

This process of comparison is repeated until all of the criteria are compared. The pairwise comparison of the reshoring criteria are shown in the table (Table 2). The absolute scale numbers (1-9) are simple and easy to use. For six criteria, a minimum of 15 pairwise comparisons are required, and the remaining comparisons are computed by taking inverse across the diagonal. After all the comparisons are made, the resulting matrix is normalized column wise, by dividing each number by the sum of all numbers in the corresponding column. Next, the sum in each row in the normalized matrix is computed and average for each criterion is taken. This gives the final normalized weight for each criterion (Table 3). The criterion with the highest weight is the most influential one in the decision. The sum of all weights of criteria should be equal to one. According to the comparison, Quality has the highest weight (0.41) and Sustainability has the least weight (0.03).

Table 2. Pairwise comparison of criteria

	Cost	**Quality**	**Time**	**Flexibility**	**Innovation**	**Sustainability**
Cost	1,00	0,33	5,00	5,00	5,00	7,00
Quality	3,00	1,00	5,00	5,00	5,00	7,00
Time	0,20	0,20	1,00	1,00	1,00	5,00
Flexibility	0,20	0,20	1,00	1,00	1,00	5,00
Innovation	0,20	0,20	1,00	1,00	1,00	5,00
Sustainability	0,14	0,14	0,20	0,20	0,20	1,00

Table 3. Normalized table and final normalized weights

	Cost	**Quality**	**Time**	**Flexibility**	**Innovation**	**Sustainability**	**Final normalised weights**
Cost	0.21	0.16	0.38	0.38	0.38	0.23	0.29
Quality	0.63	0.48	0.38	0.38	0.38	0.23	0.41
Time	0.04	0.10	0.08	0.08	0.08	0.17	0.09
Flexibility	0.04	0.10	0.08	0.08	0.08	0.17	0.09
Innovation	0.04	0.10	0.08	0.08	0.08	0.17	0.09
Sustainability	0.03	0.07	0.02	0.02	0.02	0.03	0.03
							Σ 1.00

In the third and final step, consistency of the weights is calculated. The reason for this step is to ensure consistency of the pairwise comparisons. This is done by calculating the consistency ratio (CR) that was proposed and developed by Saaty (1980). The CR is calculated by the equation below (Equation 1):

$$CR = \frac{Consistency\ index\ (CI)}{Random\ index\ (RI)} \quad (1)$$

The consistency index (CI) is calculated using the equation below (Equation 2) and this value comes to be 0.085. λ_{max} is called the average consistency measure and n is the number of criteria in this study.

$$CI = \frac{\lambda max - n}{n-1} \quad (2)$$

The random index (RI) value is obtained from previous studies (Saaty, 1980; 2000) and this value comes to be 1.24 for 6 criteria (Table 4).

Table 4. Average random inconsistency index (Saaty, 1980; 2000)

Number of criteria (n)	1	2	3	4	5	**6**	7	8	9	10
Random consistency (RI)	0	0	0.58	0.9	1.12	**1.24**	1.32	1.41	1.45	1.49

The calculated consistency ratio is 0.069. This value should be less than 0.10 in order for the pairwise comparisons to be consistent. Therefore, the judgements are acceptable. As mentioned earlier, there are only two alternatives, "Evaluate reshoring" and "Do not evaluate reshoring". In order to gives values to the six reshoring criteria, fifteen input (or decision) scenarios were generated. Some of these scenarios (1-10) have come from previous studies on reshoring decision making (Hilletofth et al, 2019). The remaining scenarios (11-15) have been created to further test the tool.

5. RESULTS

The weights from the AHP method is implemented to evaluate different reshoring decision scenarios (Table 5). Experts have been used to evaluate fifteen reshoring scenarios. The decision scenarios provided the necessary test data to evaluate if the results from AHP provided accurate results. Each scenario consists of sextuple values for the six criteria, with each ranging from -5 to +5. The values indicate the impact on the criteria if reshoring would take place. The output also ranges from -5 to +5, where values between -5.00 to 0.00 indicate 'don't evaluate' reshoring while 0.01 to +5.00 indicate 'evaluate' reshoring. The values of the different scenarios are multiplied with the corresponding weights and added to get the output values from AHP. The decision from the AHP output is determined depending on the output from the AHP. The values from AHP outputs and the expert's opinion are compared to see if there is any conflict in decision between the expert and AHP method.

The results indicate that for most of the scenarios there is a correct decision from the AHP output. Out of 15 scenarios, 13 scenarios did not show any conflict in the decision. The remaining 2 of the scenarios showed conflicts between the expert and AHP output. The change in decision is caused by the reversal of the direction of the output. However, it is seen that the difference between the conflicting outputs is not very large. For example, in scenario 13, the output from the AHP is -0.18 which is very small in order to make a strong decision not to evaluate reshoring. The experts suggest otherwise. Similarly, in scenario 14, the output from the AHP is 0.03, which is also very small in order to make a strong decision to evaluate reshoring. Again, the experts suggest otherwise.

Table 5. Input decision scenarios and decision evaluation from AHP

Scenarios	Criteria (final weights)						Expert's opinon	Output from AHP	Decision from AHP output	Conflict between expert's opinion and AHP
	Cost (0.29)	Quality (0.41)	Time (0.09)	Flexibility (0.09)	Innovation (0.09)	Sustainabilty (0.03)				
1	-5	-1	-3	-2	-3	3	-5	-2,49	Do not evaluate	No
2	2	5	-1	3	4	1	4	3,21	Evaluate	No
3	-3	-4	-3	-1	4	-1	-4	-2,56	Do not evaluate	No
4	3	-4	-1	-3	-5	-3	-4	-1,67	Do not evaluate	No
5	-4	-2	5	-1	-1	5	-4	-1,57	Do not evaluate	No
6	4	2	-4	2	2	-5	4	1,84	Evaluate	No
7	-4	2	1	2	2	5	4	0,26	Evaluate	No
8	2	-1	3	-1	1	5	3	0,58	Evaluate	No
9	3	5	5	2	5	-3	5	3,92	Evaluate	No
10	-3	-5	3	-2	5	-2	-4	-2,47	Do not evaluate	No
11	0	0	0	0	0	0	-3	0,00	Do not evaluate	No
12	3	-4	2	-2	-2	2	-3	-0,90	Do not evaluate	No
13	-5	0	3	5	5	4	3	-0,18	Do not evaluate	Yes
14	-5	4	2	-1	-4	3	-3	0,03	Evaluate	Yes
15	-2	-5	-5	-2	-5	5	-5	-3,57	Do not evaluate	No

6. DISCUSSION

There is a lack of decision-making support tools for reshoring decisions which has also been a high priority for research (Stentoft et al, 2016; Barbieri et al, 2018). The existing decision support and frameworks have only been theoretical exercises and hence is insufficient support on how firms can practically use such theoretical frameworks or models to make a resilient reshoring decision (Joubioux & Vanpoucke, 2016; Gray et al, 2017). Within the domain of operations management, there are several decision support tools and one such tool is the AHP (Subramanian & Ramanathan, 2012), for example, AHP has widely been applied for supplier selection process (Chai et al, 2013), facility selection (Chang & Lin, 2015) and outsourcing decisions (Schoenherr et al, 2008). However, there is little evidence of application of AHP for reshoring and more research in using this technique is recommended in the reshoring domain (Sardar et al, 2014). This study has explored the feasibility of AHP decision-making tool for reshoring decisions. The results have shown that AHP is feasible for most reshoring decision making situations. Out of 15 reshoring scenarios, 13 of them were correctly evaluated by the AHP process. For most of the decision scenarios, the output from the AHP has the same evaluation as that of the expert. Only two of the evaluations has indicated an evaluation from the AHP different from that of the expert. However, the confidence level, indicated by the magnitude of the output was very low for these scenarios.

This problem could be mitigated by fixing more than two output evaluations for such close values. The advantage of the AHP method is in the determination of consistency of the comparisons.

In the AHP decision making tool for reshoring decision, both qualitative and quantitative criteria can be applied, which makes it a very powerful tool for decision makers today (Schoenherr et al, 2008). Moreover, it supports automatic and digital decision support. In this study, six reshoring criteria were used on an overall level, that is cost, quality, time, flexibility, innovation and sustainability, since they also represent the common competitive priorities (Sansone et al, 2018; Hilletofth et al, 2019). On the competitive priorities level, AHP is found to be feasible method. This is because it gives the decision maker a reasonable number of criteria to deal with. In order to make it further sophisticated, the AHP should be implemented on a sub-criteria level. This can be done by conducting similar pairwise comparisons at the sub-criteria level as well. In this study, the reshoring decision is looked upon from a purely competitive priorities' perspective. It is also possible to include other criteria related to the specific location; such as, market conditions or governmental policies (Sardar et al, 2014). However, in comparison to other studies, most of the them have focused on criteria emerging from competitive priorities and some of these have the highest priority weights (Chang & Lin, 2015; Kannan et al, 2008; Dweiri et al, 2016). The criteria Cost and Quality have been important among other AHP applications in operations management as well. In this study as well, the Quality criterion has the highest weight of 0.41, followed by the Cost criterion having a weight of 0.29. This suggests the importance of cost and quality in a reshoring decision (Johansson & Olhager, 2018; Kinkel & Maloca, 2009; Kinkel, 2012). The output results from this AHP study indicate a high percentage of correct evaluations between the expert and system. Therefore, the AHP can simulate the expert for a large share of occasions.

The AHP decision tool used in this study is automatic and sophisticated. This is because it gives an immediate decision evaluation on entering the scenarios. Moreover, the AHP process allows the decision maker to follow the reshoring decision process in a systematic manner using pairwise comparison (Schoenherr et al, 2011; Pearson, 2001). By comparing the criteria pairwise, the complex problem is broken down into a series of smaller ones which are simple for the decision maker (Brunelli, 2015). Therefore, using a hierarchy of criteria simplifies the reshoring decision making (e.g., Sequeira & Hilletofth, 2019). However, this requires the decision-maker to have sufficient information on the criteria and their inter-relationships formed through previous knowledge or experience (Saaty, 1980; Vaidya & Kumar, 2006). The construction of hierarchy of criteria can be adapted to different decision-makers or companies and for different reshoring types (Gray et al, 2013).

7. CONCLUSION

The aim of this paper was to investigate the feasibility of AHP for reshoring decision making. In order to achieve this, AHP was applied to six reshoring criteria. The pairwise comparisons in the AHP were performed by an expert in the reshoring domain and the priority weights for the criteria were obtained. It was found that the cost and quality criteria had the highest priority weights. The priority weights were used to evaluate fifteen reshoring scenarios. The output from the AHP was compared with expert's opinion. It was found that for most of the reshoring scenarios, the evaluation from the AHP was in alignment with that of the expert. Hence, this research proposes that AHP is a feasible tool for reshoring decision making and the confidence of the decision is indicated by the magnitude of the evaluation. The criteria used in reshoring decision consists of firm's competitive priorities. The pairwise comparison of the criteria depend on the decision makers previous knowledge of the criteria, hence the AHP can be easily adapted for different reshoring contexts.

For future research, it would be necessary to incorporate some uncertainty into the decision making, since reshoring decisions are taken under uncertain information (Hartman et al, 2016). In this study only fixed integer values were used in pairwise comparisons. It would be interesting to use fuzzy integers for uncertainty. In order to incorporate uncertainty, fuzzy logic and fuzzy AHP are promising methods (Zadeh, 1965; Ross 1997; Chan et al, 2008). Moreover, the current AHP can be extended to a sub-criteria level to make the decision more robust and multiple output evaluations could be implemented. Also, for future research, it would be more realistic to include multiple decision makers since in large companies, a complex decision such as reshoring is taken among multiple decision makers, such as boards, team of experts and number of managers. Their evaluations may differ from each other (Saaty, 1989). There are many ways of using AHP as a group decision making method (Brunelli, 2015).

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