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Performance Assessment of R&D-Intensive Manufacturing Companies on Dynamic Capabilities

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ABSTRACT

In today's business landscape, improving competitive advantage of manufacturing companies depends on their continuous performance improvement. This necessitates a generic and multi-dimensional view that organisational and managerial processes should be assessed by the underlying micro-foundation of dynamic capabilities (DC) in conjunction with enhanced new product development (NPD) projects. This study aims to propose an operationalised model of the conceptual DC framework including sensing, seizing, and reconfiguration capacities. The advantage of the two aforementioned models, which are based on a multi-criteria decision analysis (MCDA) framework, is that they can assist managers in the automotive industry to identify improvement plans and goals for sound and robust decision making. For this purpose, the evidential reasoning (ER) approach, which is realised in the intelligent decision system (IDS) software tool, is employed to perform performance self-assessment for the selected manufacturing companies on DC. This study provides managers with a useful tool to assess their company's strengths and weaknesses in regard to the DC components.

KEYWORDS

Cluster Growing Hierarchical Self-Organising Map, Prediction, Rainfall, Support Vector Machine, Tea Export

1. INTRODUCTION

Managing innovation is important if organisations are to renew themselves, transform stagnant businesses, and increase market share (Hardy, 1994). New products can only be successfully developed when departments such as marketing, sales, R&D and manufacturing are able to reconceptualise and create knowledge and expertise for processes that cut across departments (Lau et al., 2010). New product development (NPD) process on its own is dynamic capabilities (DC) since these capabilities are to develop relevant strategies, processes and skills through collaboration with external and internal supply chain partners in order to support the NPD process and also enhance NPD performance (Verona, 1999; Mishra and Shah, 2009). To facilitate systematic innovation, it is necessary to focus on micro-foundations of DC that need to be operationalised for reinventing business processes and building entirely new markets that meet untapped customer demand (Eisenhardt & Martin, 2000;

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Teece, 2007). These micro-foundations underlying organizational and managerial processes include not only investment on R&D and intellectual property protection, but also complementary assets needed to achieve and sustain competitive advantage (Teece et al., 1997; Tecce, 2007). For this purpose, companies need to focus on higher order organisational capabilities such as DC which involve organisational routines and organisational integrations in order to outperform competitors and gain and access value capturing and creating strategy though innovation (Teece, 2018). Although, the DC based on their strategies support NPD process, it can be used to explain different firm performances (Marsh & Stock, 2006). Effective management of DC can also increase the NPD success and long-term competitive advantage (Hullova et al., 2019).

Teece (2007) defined a comprehensive generic model to capture numerous management practices in the field of DC. The DC model of Teece (2007) has been selected due to the reasons that alleviate the shortcoming of the existing DC models reported in the DC literature. There are some drawbacks surrounding the existing DC models. First of all, these models have deficiency to explain how firms achieve sustainable competitive advantage through micro-foundations. Secondly, they do not show the comprehensive view of management practices that integrate strategic and innovation management. Many previous studies have looked at only a thin slice of DC or uni-dimensional DC. According to the literature review, there is lack of empirical research to measure DC at micro-foundation level. Although a large number of criteria and indicators have been identified in many prior studies, many of them do not provide integration or aggregation in a structured and quantitative manner.

The originality of the research framework attributes to the observation that there was shortage of a comprehensive measure of DC designed specifically for the automotive industry. The focus of this study was placed on measuring DC by taking both present and future concerns of relevant purchasing, production, and R&D managers. By refining and structuring relevant criteria and indicators, this study is the first of its kind to operationalise multi-dimensional DC framework which includes the three main interrelated capacities of the DC model of Teece (2007), namely: sensing capacity, seizing capacity and reconfiguration capacity, with respect to the micro-foundations that relate to the organisational and managerial process for the NPD process. The study mainly focus on specific type of DC at supply chain (SC) relationship level where suppliers involve in NPD process extensively. The aim is to propose the DC performance self-assessment for manufacturing companies using the evidential reasoning (ER) approach as a powerful multi-criteria decision analysis (MCDA) tool that is useful for dealing with both quantitative and qualitative information with subjective judgments of ambiguity. The ER approach is implemented in the intelligent decision system (IDS) software tool for multiple criteria performance assessment (Xu & Yang, 2001). The proposed MCDA method provides an operational means to assess a company's DC performance. Regarding the novelty of methodology, the ER approach and the IDS software are employed to generate the average performance scores of DC. This research also identify the relevant main decision variables and refined measurement items through case studies and the literature review, which are related to suppliers, customers and internal functions in the context of NPD process, thereby contributing to the existing knowledge in the SC and NPD literature. The MCDA framework for company performance self-assessment is validated and tested in manufacturing companies.

2. LITERATURE REVIEW

2.1 Dynamic Capabilities

Over the past two decades, the DC approach (Teece et al., 1997) has become one of the most influential research areas in the field of strategic management (Helfat & Peteraf, 2015; Schilke, 2014). DC underpin not only value creation but also value capture from innovation (Teece, 2018). Accordingly, the existing literature also proposes that three types of DC including innovation capabilities, environmental scanning and sensing capabilities, and integrative capabilities are essential for ecosystem orchestration (Helfat and Raubitschek, 2018).

A central part of the innovation process concerns the way firms go about organising search for new ideas that have commercial potential (Laursen & Salter, 2006). Firm's sensing capacity refers to the identification and creation of opportunities by means of environmental scanning, learning and investments in R&D activities (Lichtenthaler & Ernst, 2012). Scanning also improves an organisation's capacity to react to or even pre-empt environmental changes that pose risks or provide opportunities (Eisenhardt & Martin, 2000). Sensing capability in NPD projects must sense the environment to gather market intelligence on market needs, competitor moves, and new technologies in order to identify new product opportunities for managers, and decide to engage in exploratory early-stage research activities to pursue these opportunities with new product design and prototypes (Pavlou & EI Sawy, 2011). The prior literature reported that three basic routines of the sensing capability are: (1) generating market intelligence, (2) disseminating market intelligence, and (3) responding to market intelligence (Pavlou & EI Sawy, 2011). Prior research emphasises (supply) market intelligence as one of the basic routines of the sensing capacity to improve operational efficiency internally, enhance service effectiveness, reduce cost, and increase customer satisfaction (Handfield et al., 2009). A strong sensing capacity allows for achieving strategic flexibility, first mover advantages, and responsiveness to customers (Teece, 2007).

Sensing capacity itself does not ensure superior innovation and firm performance but it provides the basis for subsequent seizing innovation opportunities, and the marginal utility of strengthening sensing capacity is relatively limited if a firm lacks seizing capacity (Lichtenthaler & Ernst, 2012). Seizing refers to the organisational strategy and infrastructure for making appropriate decisions and absorbing and integrating resources to create and capture value from opportunities (Katkalo et al., 2010). Once a new (technological or market) opportunity is sensed, it must be addressed through new products, processes or services. This almost always requires investments in integration and commercialisation activity (Teece, 2009). Seizing dimension describes the ability to address opportunity and capture the value of doing so by mobilising resources (Teece, 2012). Seizing capacity also help firms construct decision-making protocols, build trust and commitment through effective communication and control the environment (Vanpoucke at al., 2014). Seizing capacity is assessed by integration which is process by which an organisation coordinates and deploys knowledge resources (Grant, 1991). The characteristics of seizing capacity can be justified, identified and developed in the product design stage of NPD. In product design and manufacturing integration, various functional representatives like cross functional communication, which is the main antecedent of internal integration, must cooperate in order to minimise goal conflict and successfully deal with technical and strategic interdependencies inherent in technology adoption (Swink & Nair, 2007). Design and manufacturing integration activities promote and cultivate cross-functional skills and a greater mutual understanding of technology commercialisation tasks (Zahra & Nielsen, 2002). Internal integration, supplier and customer integration play an important role in the seizing capacity where exploitation of the exiting supplier and customer knowledge by the purchasing and R&D teams of the companies is characterised by a long-term commitment between the collaborators, an openness of communication, and mutual trust and partners work together to ensure high product quality and low costs, and shorten TTM (Ragatz et al., 2002).

Companies need to align and realign their identification and integration processes based on adaptation mechanisms that represent attributes of a DC lifecycle and coordination between the acquisitions of external technological knowledge with internal technology management (Lichtenthaler & Ernst, 2012). In addition to this, external technology adaptation can be carried out by the internal exploration activities (Perols et al., 2013). This definition implies that continuous NPD performance requires reconfiguration capacity that involves repeated cycles of organisational learning to make changes in operating routines (Anand et al., 2009). In the NPD context, because operational capabilities are supra-individual and do not reside in any specific individual, NPD units must integrate their individual knowledge and patterns of interaction into a collective system to deploy the new configurations of operational capabilities (Koufteros et al., 2010). This necessitate the importance of coordinating capability that enables reconfiguration by assigning resources to tasks, appointing the right person to the right task, identifying complementarities and synergies among tasks and resources, and orchestrating collective activities (Pavlou & EI Sawy, 2011). Teece (2007, p. 1338) argued that "in short, both innovation and reconfiguration may necessitate co-specialised assets being combined by management in order for (systemic) innovation to occur." To stimulate leaning and knowledge accumulation and readjustment cycles as the relationships evolve, investments in skills and routines adapted to the exchange and the development of social relationship among partners and experience with a partner would be important (Krause et al., 2007). In the study of Mishra and Shah (2009), co-specialisation assets are the ''collaborative competence'' including the supplier, customer and cross functional team involvement in NPD which modelled as second-order model and impacts on NPD performance, positively. Customers share their know-how about product improvement possibilities, new product functions; assessment of prototypes, and future product trends and customers can also provide diverse knowledge that can speed up the learning process, leading to a greater number of new products (Lau et al., 2010). The involvement of suppliers in the reconfiguration capacity is also associated with transaction costs, such as contracting, monitoring, and enforcement (Dyer & Singh, 1997; Williamson, 1985), as well as other related costs, such as coordination costs (Das et al., 2006). Mayer (2006) emphasised that supplier involvement may generate additional spill-over effects that extend beyond the direct costs and benefits of the supplier contract. Supplier involvement also provides technical knowledge, or know-how that is applied in the production environment to improve an organisation's ability to provide products and services. According to the literature, internal involvement in NPD process is related to the heavyweight product development management role which includes real authority of product development managers over personnel; the final say in budget decisions, enough influence to make things happen, and influence across the organisation (Clark & Fujimoto, 1991).

2.2 Micro-Foundations of Dynamic Capabilities

2.2.1 Sensing Capacity

In our new performance assessment model, we therefore include the following three areas for assessing a firm's sensing capability: search for new technology, voice of customer forum, and supplier innovation. There is a generic ways companies acquire new technologies which is search for new technologies (Teece, 1986; Pisano, 1990; Hayes and Wheelwright, 1984 cited in Peng et al., 2008). The success of NPD projects is truly depends on understanding of user/customer needs. Customer involvement in NPD process ensures that the feedback of customers is highly important in the innovation process within an organisation at an early stage of NPD process (Lau et al., 2010). Frontline employees put efforts in frequent interaction with potential customers on a daily basis (Swink et al., 1996). In many industries, buying firms do not only rely on the manufacturing capabilities of their suppliers, but also recognise that "suppliers have become an increasingly important source of product and process innovation" (Azadegan & Dooley, 2010, p. 488). The importance of supplier innovation necessitate the auto manufacturers to motivate their suppliers to share essential land required technological knowledge (Wagner & Bode, 2014).

2.2.2 Seizing Capacity

Our new DC performance assessment model intends to assess seizing capacity from the following areas: inter-organisation communication, trust, managing complements and platforms, and product architecture. Effective communication is facilitated through the use of open, informal channels of communication for developing and leveraging tacit knowledge which leads firms to gain sustainable competitive advantage (Nonaka & Tekeuchi, 1995; Badir et al., 2009). The effective communication is the result of openly, timely, accurately and sensitive transforming formal and informal information and tacit knowledge between SC and NPD strategic partners that improve the quality of their products, reduce customer response time, and increase cost savings (Chen et al., 2004; Paulraj et al., 2008). Trust as decision is a high level attribute between a supplier, and manufacturer is measured in terms of co-location, personal relationship, auditing the supply chain for continuity of supply, capacity, quality standards and process capability, and complaint handling (Goffin et al., 2006). Moreover, trust in this study is measured by the co-location which means that suppliers will have a team in place at a customer's R&D centres, working side by side with the development engineers. The co-location has short-term and long-term benefits including current NPD activities and sustainable competitive advantage, respectively (Ragatz et al., 1997; Chen et al., 2010). Trust is also assessed by personal relationship such as an intensive and familiar contact between the supplier and manufacture at the human level or formal, impersonal and superficial between supplier and manufacturer (Goffin et al., 2006). Finally, trust is measured by the complaint handling, which means that suppliers accept faults in a product and react quickly or slowly, and the manufacturer has to convince the supplier that the product is faulty (Goffin et al., 2006). Complementary asset is a bundle of know-how and facilitates the successful commercialisation of a technology innovation that allows organisations to capture profits (Teece, 1986). To manage firm's boundaries and complements, the importance of outsourcing decisions (make/pseudo make/buy decisions) need to be taken into account. One class of specialised complementary assets such as design for manufacturer (DFM) is used for reducing product changeover costs and process variability, thereby improving both productivity and product quality (Swink & Nair, 2007). The calibrating asset specificity explained by the specifications of assets is a production engineering requirement in manufacturing, which generally has considerations such as component size, machining parameters and process capability. The controlling bottleneck asset is assessed by the load versus capacity strategies that are used to analyse customer demand against plant asset capacity. The adaptation of advance manufacturing technology (AMT) in the process innovations is likely to be governed by the appropriability regime which depends on the features of previous core experience and tacit knowledge in process capabilities (Teece, et al., 1997). The product modularity help a company to create value for customers and in turn make profit. Ulrich defines product architecture as ''the scheme by which the function of a product is allocated to physical components'' (Ulrich, 1995, p. 419). Product modularity deals with a number of features of product components, including commonality, reusability and standarisation (Lau et al., 2009).

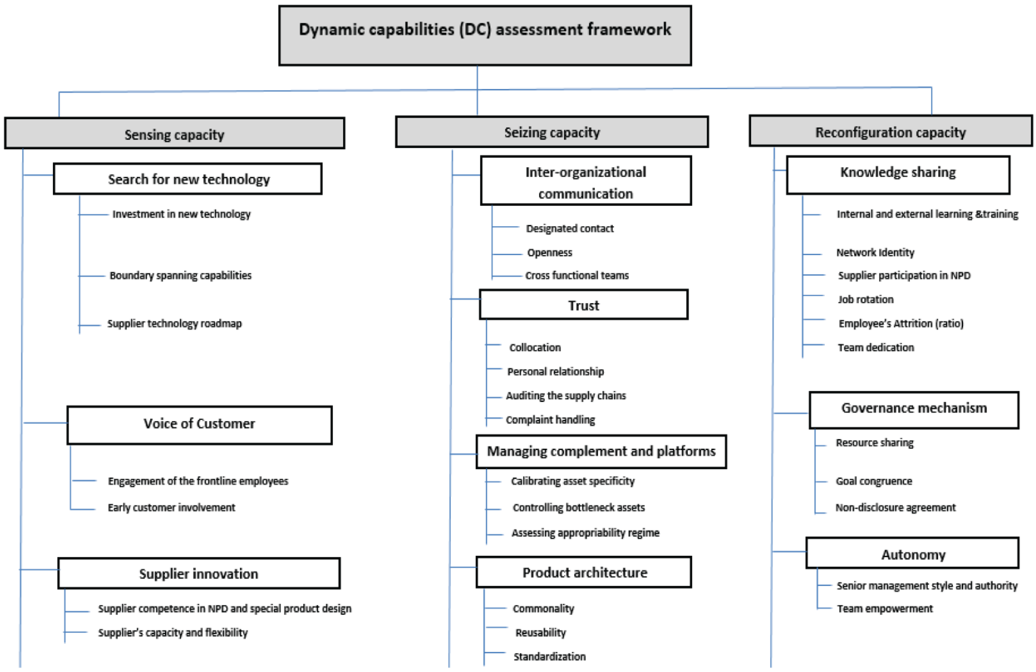
2.2.3 Reconfiguration Capacity

Internal learning refers to the training of employees at different functional levels (Huang et al., 2008). The learning referred to the process that project team generate or obtain knowledge in performing NPD activities through acquiring, processing, and assimilating information (Chen et al., 2010). Furthermore, creating a strong network identity facilitates multidirectional knowledge flows using supplier association, consulting teams/problem-solving teams, voluntary learning teams and inter-firm employee transfers (Lawson and Potter, 2012). The level of incentives for motivating members to participate in NPD activities and openly share valuable knowledge while preventing undesirable spill-over to competitors and efficiently transfer knowledge both explicit and tacit is used to assess knowledge sharing (Dyer & Nobeoka, 2000). One of the ways to transfer knowledge in NPD process is job rotation specifically rotating managers that utilise a knowledge sharing mechanism (Pagell, 2004). Finally, team dedication is another way of knowledge sharing that team members are committed to conduct NPD activities, contributing to measuring the knowledge sharing (Chen et al., 2010). Governance mechanism is an enabler of knowledge sharing through resource sharing, goal congruence and non-disclosure agreements in order to ease the technological knowledge transfer while protecting intellectual property rights from spill-over effects ((Luo, 2000; Teece, 2007; Cao & Zhang, 2011). Resource sharing is measured by using cross-organisational teams, sharing technical supports and equipment (e.g. computers, networks, machines) and pooling financial and non-financial resources (e.g. time, money, and training) between company and SC partners (Cao & Zhang, 2011). Resource sharing is also associated with significant cost advantage and competitive advantage through cost position or differentiation (Porter, 1985). Goal congruence is assessed by the goals and agreement on the importance of collaboration and improvement that benefit company and SC partners through working towards the goals of the SC (Cao & Zhang, 2011). Autonomy refers to decentralisation of decision-making power to those who will actually carry through the work, and also represents the ability to deviate from a detailed plan (Das & Joshi, 2007). The senior management style and authority is measured by the level of involvement of senior managers that deal directly with the workforce rather than have supervisors and team leaders in place, and also the level of engagement and motivation of firm's employees and NPD team members. Team empowerment is evaluated by the degree of a project manager's power to make decisions regarding resource allocation, interim schedule targets, and other project-related matters (Chen et al., 2010).

2.3 MCDA

MCDA has been widely used for various application of business management that can be applied for performance assessment and decision making under multiple criteria and/or alternatives (Sen & Yang, 1998; Xu & Yang, 2001). Most of the MCDA problems are associated with a range of alternatives and set of criteria with different units and measurements (Xu & Yang, 2003). MCDA tools which are common methods for performance analysis in the literature are explained to analyse multi-dimensional performances. Among MCDA methods, simple additive weighting (SAW) is reported as one of the most popular techniques because of its transparency and ease of implementation (Velasquez & Hester, 2013). The main concern surrounding the SAW is that this method is open to complete compensability and the loss of original information (Belton & Stewart, 2002). Weighted geometric mean (WGM) is another aggregation method that overcomes the shortcoming of the SAW method by assigning a greater penalty to the aggregated value of an alternative when there is a low score assigned to it for at least one criterion (Velasquez & Hester, 2013). However, a critical assumption of the WGM method is that each criterion has an absolute power to decide the existence of any alternative (Velasquez & Hester, 2013; Zhou et al., 2010). In AHP, the problem is defined into a hierarchical structure by having the goal at the top level, criteria (and sub criteria) at the intermediate levels, and decision alternatives at the lowest level (Saaty, 1980; Sen & Yang, 1998). However, a significant limitation of AHP is the requirement for paired comparison between two alternatives for each criterion/indicator (Sen & Yang, 1998). Since the aim of this paper is not to explore the most high performance company on DC or to rank several companies regarding their DC but the aim is to generate a practical assessment method to enable a company to conduct a self-assessment and for this purpose, the AHP may not be a practical method without an alternative for comparison (Sen & Yang, 1998; Velasquez & Hester, 2013). Data envelopment analysis (DEA) is a nonparametric frontier estimation methodology based on linear programming for measuring the relative efficiency of a set of comparable decision making units (DMUs) that possess shared functional goals (Zhou et al., 2008; Velasquez & Hester, 2013;Wong et al., 2009). However, there are some limitations for DEA that include the significance of the results which depends on whether the DMUs in the peer group support the real best performers or not. This is the critical issue that avoid applying for DEA for DC assessment which depend on a large number of criteria since gathering all the related information from a large number of companies is difficult (Velasquez & Hester, 2013). Additionally, the assumption of DEA that outputs will be increased when adding more inputs into the process may not always be correct. Similar to AHP, DEA may not be a practical method for a self-assessment within a company without other alternatives for comparison (Velasquez & Hester, 2013). TOPSIS is another prevalent technique that can be applied for a large scale problem including large numbers of criteria and alternatives to score and rank alternatives based on selecting the alternative having the shortest distance from the positive ideal solution (PIS) and

Figure 1. MCDA model on DC assessment



the longest distance from the negative ideal solution (NIS) (Velasquez & Hester, 2013; Sen & Yang, 1998). There are limitations concerning this method that include the inability to deal with qualitative criteria which are difficult to quantify exactly (Huang & Li, 2012). Finally, similar to AHP and DEA, the composite result is sensitive to the group of alternatives being compared and therefore, it might be applicable for ranking alternatives but not for self-assessment within a single company.

In the literature, there are different MCDA methods which include non-compensatory, which do not allow any kind of trade-offs between the attributes and compensatory which allows trade-offs (Sen & Yang, 1998). ER approach is one the compensatory MCDA methods in which an attribute of an alternative is based on the belief structure and used to handle uncertainties like absence of data, incomplete description or random nature of an attribute in the MCDA problem (Xu et al., 2006). The ER approach has been suggested as an effective tool to reasonably integrate qualitative judgements with quantitative measures in complex and uncertain situations. Compared with other methods, ER approach uses a belief decision matrix for a distribution instead of a single value to show an alternative's performance on an attribute.

2.4 Developing the DC Assessment Framework

Figure 1 illustrates the MCDA model of multi-dimensional DC assessment of manufacturing companies, which evolves primarily from and is intended to operationalise a conceptual DC model proposed by Teece (2007). This model is also the result of systematic analysis of the literature reviews on operation management scholars in order to show the precise and comprehensive criteria and measurement items for assessing the DC level of companies. This operationalised DC model is tested on multiple case studies for the purpose of performance self-assessment of manufacturing companies on DC.

3. RESEARCH METHODOLOGY

ER approach as the powerful tool in MCDA is conducted to create data for capturing the performance score of DC. This means that the data generated as average performance scores (%) for sensing, seizing and reconfiguration. Assigning weights and assessment grades to the attributes enables the companies to be ranked and a sensitivity analysis of the rankings is conducted to verify the effect of change in weights for each capacity and their relevant attributes. Since the performance assessment of the companies on DC using MCDA need the weights for each criterion, the questionnaire has been prepared using Likert scale for generating weights of each DC criteria. The first part of questionnaire for DC assessment is related to determination of the weights of the criteria using the Likert scale from 1 to 5 to rate the relative importance of items and its relevance to the top attributes. The translation of the scale is described below:

Scale 1 = Very low/Not applicable
Scale 2 = Low
Scale 3 = Medium
Scale 4 = High
Scale 5 = Very high

The second part is to assess the relevant items for the DC assessment of the companies in conjunction with different NPD projects completed during last three to five years. The questionnaire was sent to the relevant practitioners in industries to express their judgments for the relative importance of criteria and sub criteria for the sake of aggregating data for DC assessment. It is common that each attribute is of different importance to its upper level attribute. The results from the respondents concerning the weights of each criterion inserted into IDS in the section of weight elicitation using visual scoring method. Table 1 shows that respondents or decision makers with the knowledge of SC, NPD projects and performance measurement systems participated in the survey and their answers were collected and analysed in order to provide data in IDS software using visual scoring method to calculate relative importance of sensing, seizing, reconfiguration capacities. The weight elicitation process was conducted on April 2015.

The relevant respondents completed the surveys on April and May 2017 for the purpose of performance assessment of companies on DC framework through MCDA. Their answers were extracted and analysed through rule based transformation technique and inserted in IDS software for the assessment results. Total responses for DC assessment through online survey is 7. However, another set of responses was at a different period of time which was February 2017 and April 2015 which provided other responses through email communication, in total there were 25 responses for DC assessment. For the self-performance assessment of the companies, the online survey through Survey Monkey has been designed and sent out to them. The automotive industries are one of those industries where the role of the supplier in concept and engineering design as the main phase of NPD processes is so important. While these two phases incur only 5-8% of the total product development costs, these two activities commit or ‘locked-in’ in 80% of the total cost of the product and decisions made early in the design process can have a significant impact on the resulting product quality, cycle time and cost (Ragatz et al., 1997). All selected companies with different culture and structure for managing their NPD projects believe that DC development as a strategy could be implemented to assist them to enhance their completive advantage and also improve performance measurements. In addition to this, the companies are similar on factors such as the importance of innovation in materials, product and design and achieving sustainability competitive advantage through DC.

The IDS package that facilitate the ER approach is used for the comprehensive DC assessment of companies that provides a structured knowledge base to help decision makers at the top level of the company to make judgements concerning the strength and weakness and also the area of improvement.

Table 1. Positions of respondents of manufacturing companies for weight elicitation

Decision Makers (DMs)	Positions
DM1	R&D Manager from Cummins Inc., USA
DM2	Executive Director from Cummins Power Generation, USA
DM3	General Manager, Product Planning group Cummins Power Generation, USA
DM5	Executive Vice President - Quality & Continuous Improvement - Rolls-Royce (R-R) Aerospace Division Global Supply Chain from Rolls-Royce Aerospace, UK
DM6	Production Engineering Manager, Powertrain Manufacturing Engineering, Jaguar Land Rover, UK
DM7	Tooling Engineer, Jaguar Land Rover, UK
DM8	Manufacturing Engineer, Jaguar Land Rover, UK
DM9	Principal, Jaguar Land Rover, UK
DM10	Manufacturing Engineer Machining, Jaguar Land Rover, UK
DM11	Principal Engineer – Gauging, Jaguar, Land Rover, UK
DM12	Process Engineering, Jaguar Land Rover, UK
DM13	Forward Planning Engineer, Jaguar Land Rover, UK
DM14	Project Coordinator, Jaguar Land Rover, UK
DM15	Tooling Engineer, Jaguar Land Rover, UK
DM16	Manufacturing Process Engineer, Jaguar Land Rover, UK
DM17	Senior Production Controller - supply chain manager at Nissan Motor Manufacturing Ltd., UK
DM18	Director or Manufacturing Engineering at Lam Research company, USA
DM19	Production Manager from GMN Aerospace, USA
DM20	General Manager from Volvo Construction Equipment, USA
DM21	Group Technology Manager at The Manufacturing Technology Centre (MTC), UK

The IDS is a Windows based software tool based on the ER approach. It is an evidence-based process and uses belief structures to provide the performance assessments of selected companies against DC criteria underlying qualitative judgments and quantitative measures under uncertainties and subjectivity (Yang, 2001; Xu & Yang, 2005). If the sub criteria are still too general and abstract to be measured, they should be broken down further until they are measurable. The process leads to the formation of a criterion hierarchy. IDS provide user friendly interfaces to document the alternatives and construct the criterion hierarchy as depicted in the figure 2.

In terms of attributes and their assessment grades in IDS, the definition of the attribute includes the following information: its name, whether it is qualitative or quantitative, if qualitative how many grades will be used to assess it and what are the names, meanings and utilities of the grades. This hierarchical structure can be changed whenever necessary; existing attributes can be deleted and new attributes added anywhere as required. Depending on practical appropriateness, different attributes may use different grades. For the Overall DC criteria, the following five evaluation grades are used {Worst, Poor/Bad, Average, Good, Best}.

Elicitation of preference of decision makers is another stage in IDS which is concerned with the preference or risk attitude measurement of decision makers towards the performances of an alternative on each criterion (Yang, 2001; Xu & Yang, 2001). The measurement is conducted by using a common scale, normally between 0 and 1, where 0 refers to the least and 1 the most preferred levels of a

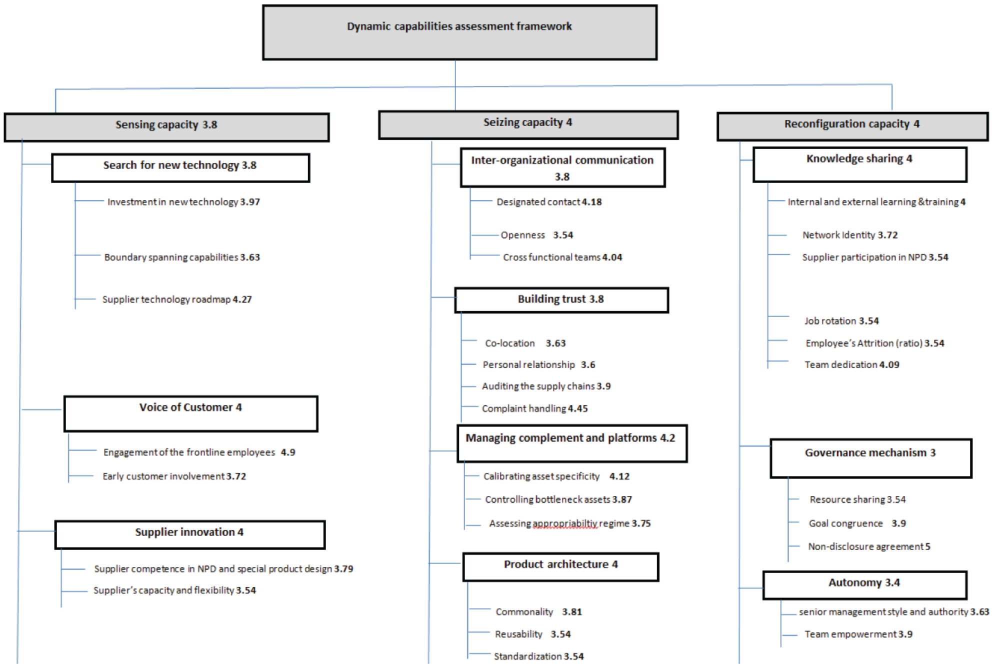
Figure 2. IDS main window and the DC approach criteria hierarchy

performance, respectively. Such a common scale is referred to as utility function in decision theory. Through the use of utility functions, alternative options can be assessed on each criterion using its own most appropriate scale first and then the assessments are transformed to the common scale (Yang, 2001). IDS has such information transformation procedures built-in to ensure that, although different assessment grades are used, decision makers' preferences are equivalently preserved in the transformation processes and properly presented in the aggregated outcomes (Xu & Yang, 2001).

In evaluation grade system and convert grades, the three sets of grades are different in numbers and wordings. When IDS detects such differences in grade definitions between two levels of attributes, it will prompt the user to convert the grades of lower level attributes to those of the associated higher level attribute (Xu & Yang, 2003). The conversion can be conducted using the rule or utility based information transformation techniques (Yang, 2001). If the user does not wish to conduct the conversion himself, the IDS will conduct the conversion based on the assumption that each set of the grades is evenly distributed in the utility space (Xu & Yang, 2005). The rule based transformation technique in the IDS software has been applied in order to convert the defined and appropriate evaluation grade for each DC criteria and sub-criteria into the original evaluation grade system that are used as {Worst, Poor, Average, Good, Best}. Each evaluation grade of the relevant criteria in the questionnaire has been defined with respect to definition, nature and the interviewee's evidence. This process has been defined for each criterion in the IDS software. All the responses that have been collected from DC surveys, have been analysed and extracted into Excel software for the simplicity and then the transformation has been conducted in the IDS software.

For example, to assess investment in new technological development, the involvement of suppliers at an early stage of product-proceeding technological development as DC sub-criteria has been evaluated with three evaluation grades of extensively used that is equivalent to best, used to some extent which is equivalent to 0.2 poor/bad and 0.8 average and finally, not used is equivalent to worst. In the definition of evaluation grade assessment, the utility value of each grade in the IDS has also been defined as 1 for extensively used, 0.5 for used to some extent and 0 for not used. In IDS, the meaning of each measurement item needs to be clearly specified by the practitioners or literature review in order to assign the appropriate evaluation grade and transformation, as well. The main issue surrounding the limitation of IDS that employ ER approach is that the main assumption in the MCDA analysis using IDS is that assessments on criteria are independent of each other. However, general interdependency between criteria, other than independency provide a deeper inside for DC assessment of companies.

Figure 3. Weighted DC assessment framework



4. RESULTS AND DISCUSSION

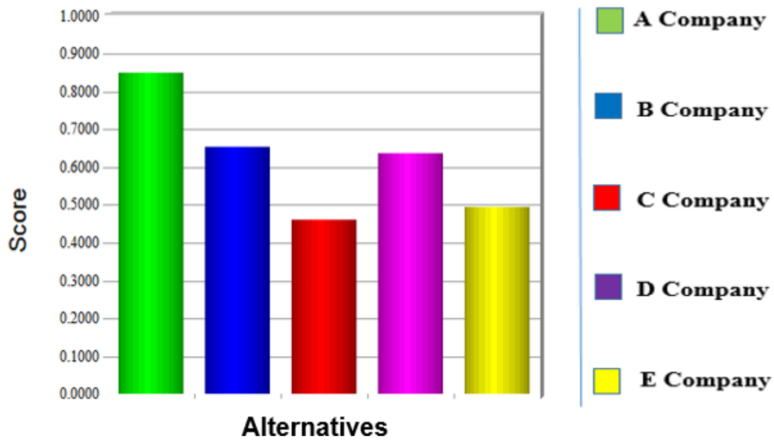
4.1 Relative Importance of DC Attributes

Figure 3 shows a comprehensive view of the relative importance of all DC attributes. In this figure, the sensing capacity with 3.8 out of 5 is the area that needs to be taken into account for improvement. The relative importance of seizing capacity and reconfiguration capacity is at a balanced level with 4 out of 5. In the sensing capacity, the most important criteria are the voice of customer and supplier innovation with significant importance of engagement of the frontline employees. From the other side, the supplier's capacity and flexibility received a minimum value for the weight of 3.54. In the seizing capacity, managing complement and platform and then the level of product modularity is on the highest level of importance with 4.2 and 4 respectively. However, in spite of the significant importance of trust and communication, these two criteria are on the minimum level of importance. The surprising point would be the highest level of importance of company handling that belongs to measuring trust with 4.45. In the reconfiguration capacity, the non-disclosure agreement that is used for assessing governance mechanisms has the highest value of relative importance with 5 out of 5. The governance received the lowest weight compared with other DC attributes in the model. Finally, knowledge sharing is the most important criterion with significant attention on the role of internal and external learning following with team dedication.

4.2 Performance Analysis on DC Assessment

In this section, the vigorous self-assessment results through IDS software tool, ensure companies that the assessment outcomes are reliable and robust and the results can be interpreted at any level and on any criterion. Such an assessment process also enable companies to identify the area of strength and weakness for continuous performance improvement (Xu et al., 2006). In the following figure and tables, Company A is American (motor manufacturing, vehicle and engine manufacturing and provides engine for industrial transportation, heavy trucks and equipment for movement); Company

Figure 4. Performance scores of DC on selected manufacturing companies



B is European (motor manufacturing); Company C is Japanese (motor manufacturing); Company D is European (Aerospace and manufacturing) and Company E is American (Aerospace and manufacturing). The following sections include the discussion on performance implication of DC, its dimensions and belief distribution assessment of DC on selected manufacturing companies. Each section summarises the key learning points following with the relevant evidences collected by the respondents of each company to explain and interpret the varying MCDA results on DC assessment.

According to the comparison of the results depicted in the tables 2, 3, 4 and 5, the A Company is highest on seizing capacity with the belied degree of 73.65 percentage best compared with sensing and reconfiguration capacities. The company is weak on reconfiguration capacity with 2.88 percentage worst and this is the area of improvement. Similarly, the other company named B is highest on seizing capacity with the 45.51 percentage best. However, this company is the highest in sensing capacity with 52.13 percentage average. The area of improvement for this company is sensing capacity although the C Company is highest on sensing capacity with the belief degree of 33.88 percentage, this company has the 51.56 percentage worst on this capacity which totally shows that area of improvement for this company is sensing capacity. In addition to this, the C is highest on seizing capacity with 46.83 percentage average. D company is strong on sensing capacity with a degree belief of 42.48 percentage best. Moreover, the D is highest on seizing capacity with 61.32 percentage average. Therefore, the area of improvement for this company is reconfiguration capacity. Finally, the E company is highest on sensing capacity with 35.27 percentage best on sensing capacity. In terms of average, this company

Table 2. MCDA results on DC assessment (%)

	Dynamic capabilities (DC)	Sensing capacity	Seizing capacity	Reconfiguration capacity
A Company	85	82	87	78
B Company	65	62	65	65
C Company	46	41	52	47
D Company	64	77	65	52
E Company	49	69	45	36

Table 3. Belief distribution assessment of selected companies on sensing capacity (%)

	Worst	Poor	Average	Good	Best
A Company	1.08	0	17.52	31.27	50.14
B Company	8.02	0	52.13	13.73	26.12
C Company	51.56	0.3	12.88	1.38	33.88
D Company	0.94	0	30.59	25.99	42.48
E Company	4.45	0.67	45.81	13.8	35.27

Table 4. Belief distribution assessment of selected companies on seizing capacity (%)

	Worst	Poor	Average	Good	Best
A Company	0	0	25.64	0.71	73.65
B Company	11.84	6.32	35.45	0.88	45.51
C Company	22.18	0.37	46.83	9.9	20.71
D Company	0	0	61.32	18.11	20.57
E Company	15.37	1.73	76.79	0.55	5.56

Table 5. Belief distribution assessment of selected companies on reconfiguration capacity (%)

	Worst	Poor	Average	Good	Best
A Company	2.88	15.5	14.36	3.1	64.16
B Company	14.56	6.95	26.09	10	42.4
C Company	33.61	5.71	25.57	8.92	26.2
D Company	2.75	16.09	56.46	18.12	6.58
E Company	31.7	25.4	16.94	18.16	7.81

is highest on seizing capacity with a 76.79 percentage belief degree. This company needs to leverage its resources and invest heavily in reconfiguration capacity.

As highlighted by the company's respondent, *''High volume of NPD / NPI and manoeuvrability''* is common place and key factor which shows high level of DC for A which has been illustrated in the table 2. Sensing and seizing capacity have been achieved high scores as generally *''overall volumes are static and there is a high correlation between 'new OEM build volume' and 'After Market volume'. Full time team allocation to NPD due to volume of projects and on-site test facilities, assembly processes and CAD modelling technology which give a high level of autonomy in NPD are the main reasons that why* A *is high on NPD performance (Effectiveness and Efficiency)''*. According to the table 1, sensing capacity in A is high because there is a need for a large amount of capital and funds to develop product proceeding technology (PPT) for investing in new technology in order to address solutions for new technologies. In fact, manufacturing companies will be able to achieve competitive advantage by how much they invest in resources to develop new products in short period of time.

According to the respondent's view of A *''…we do it right at the first time, at the right cost and with the right quality''*. The importance of upfront PPT technology developed by A for fuel consumption reduction, noise attenuation and durability is another key learning point that underpinned the high level of sensing capacity. A is also strong on sensing capacity due to identification and analysis of the risk and failures stated by the existing customers and meet the latest customer requirements in an early design stage of NPD. As expressed by the chief executive of A, *''…Our customers were the US Army soldiers and they were frequently involved by helping us to define the design requirements as well as to help us figuring out the typical failures they experienced with their previous product. Also learning upfront their critical needs helped us to propose a design that would pass their requirement at the early stage of the design''*. The company also makes use of VOC forums to build sensing capacity. According to the evidence collected by one of respondents of A, *''the company always keeps the design team members updated on changing customer tastes and requirements and reduces the high degree of uncertainty accompanying new applications in the industry''*. The level of sensing capacity in A is high due to developing prototype testing programs and involve suppliers early in the process. As highlighted by respondent, *''...involving Vendors early in the process was extremely important for the success of the program''*.

According to the table 2 and figure 5, A is also strong on seizing capacity because of high level of inter-organizational communication. There is evidence that *''...more modern communication systems, video conferencing plus engineering tools to do more simulation and less real tests (too expensive) ...was the constant communication process among* A *and the Army reviewing the program, its progress and outcome. This was the way to avoid surprises in both sides''*. Furthermore, A is strong on seizing capacity as there are always clear partnership upfront transparency, systems integration capability and people's capability and ethics. Also, there is always a level of interdependency between the two entities which make a long term relationship. According to table 2, the level of reconfiguration capacity in A is high which can be explained by the high level of internal and external learning and training especially through E-learning courses to employees and channel partners. Furthermore, the company mainly focus on clear performance management system monitoring employee performance and their individual development requirements. Thereby having programmes in place to develop people depends on their skills and capability. According to the view of one of respondents, *''the company has a structured NPD process, with key deliverables, metrics and management gates''*. Finally, the level of encouraging employees to make decisions and suggestions for improvement of process and products is high. *''Employees also identify areas of improvement as part of kaizen technique, and other improvement programs''*.

As shown in the table 2, the performance score of B on the DC has received the second ranking of 65% which is quite close to D's score of 64%. In terms of sensing capacity, future success will be based on a continuous process of anticipating new market trends. In addition to this, the strategic plan and proprietary scenario-mapping help the company to identify the biggest and fastest-growing opportunities in the industry. The company is also customer focused, which means bringing the VOC into the business by asking more customers than ever before to give their feedback and by implementing a record number of new developments as a result of their input. Customers are engaged throughout the product creation and development processes to ensure that all products meet their needs and expectations. In terms of seizing capacity in B, the speed of adoption of new technologies will depend on the interaction between consumer demand and regulation, leading to greater uncertainty. In terms of reconfiguration capacity in B, the assimilation of best practices from prior experience and external benchmarking, facilitating continuous improvement year on-year is another important aspect of reconfiguration capacity. In reconfiguration capacity in B, every employee has been asked to contribute and to generate ideas to improve how everyone works. According to the view of company's respondent, the consideration of market segment and its impact on the TTM is very important factor. In fact, the market segment following with type of technology cycle that need to be applied for NPD projects explain the varying results and what differentiate the company with other competitors. As highlighted by the B company's respondent, *''70-80% of vehicle technology can be generic with often a small amount specific to the company or model. Car companies routinely have core platforms that generate multiple models. I.E. a small car platform and a large car platform. This is the strategy we use at* B *and many other automotive companies''.* Good companies are the ones that have long term technological development. Cultural element is another key factor that distinguishes the European companies such as B with other competitors like C as Japanese car manufacturer on DC and NPD performance results. Indeed, Japanese companies focus on marketing and customer satisfaction heavily. This can be a reason to show the high level of NPD effectiveness of C. The other key differentiator factor is the approach that how much resources companies need to apply to the NPD programme development. As expressed by respondent of B company, *''...Western companies like* D *use this approach quite often to have upfront investment to get it right rather than spending so many times at each NPD gate which effect on cost, time and quality negatively''.* There are more key differentiator factors which are based on techniques between Western and Japanese companies including Keretsu; Kentou; and Simultaneous Engineering. As expressed by the respondent of B company, *''in practice western companies endeavour to copy these techniques but have never achieved the integration that the Japanese have''.*

As illustrated in the table 2, the performance scores of the seizing and reconfiguration in C are higher than sensing capacity. This mean that C is also strong on reconfiguration because continuous improvement in this Japanese company is quite strong. C is the lowest on DC and the reason has been expressed by the company's respondent that *''as project changes are minimal unless vehicle safety EURO NCAP is compromised. Project changes often affect external supply chain greatly as bought out parts (BOP) in automotive is very high, therefore a project change can impact multiple suppliers which can compromise trial and start of production (SOP) timings''.* Accordingly, sensing and seizing capacity scores are low. This is due to this fact that *''as volumes and market trends are very volatile and company business models strives towards build to customer order''.* C Company has the lowest score of 46% on the DC performance as depicted in the table 2. This can be also explained by the factors such as its lower level of R&D investment than others, as C has mostly focused on the engineering process and too many of its resources have been devoted to the engineering process. Accordingly, one of respondents explained that ''C *focus more on engineering and manufacturing process and less time is devoted on focusing on marketing and new model instruction.* Furthermore, a lack of significant direct contact with customers, and low levels of communication and coordination between engineering and production sometimes lead to problems of design manufacturability in C (Clark & Fujimoto, 1991). According to the evidence collected from C, ''*there are no external customer involvement and only internal employees as customers at vehicle trial stage. Within* C, *the target customer range is very wide on any platform size. However, the vehicle offering is very narrow on small, medium and large vehicles''.*

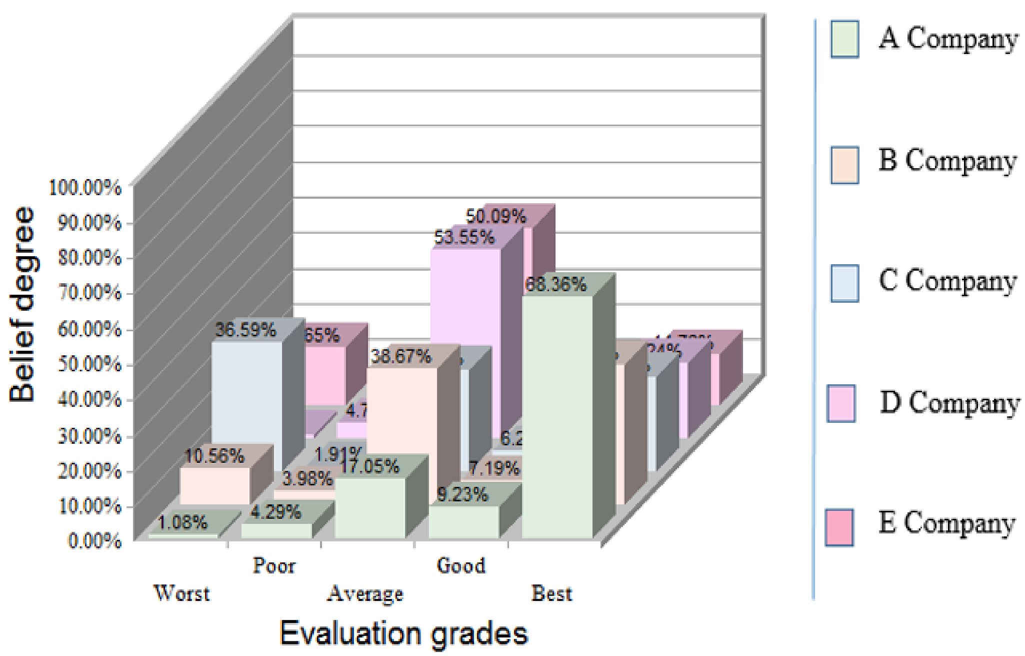
According to the Table 2, the D company has the relatively high level of sensing capacity with a score of 77% and then seizing capacity with a score of 65%. The reconfiguration capacity in D is average with a score of 52%. In the sensing capacity, D is aligned to an advanced manufacturing resource facility to tap processes and developments in exogenous science and technology. Moreover, the company makes use of VOC forums strongly in order to get external market feedback and performance criteria against the prototype product. D has a relatively small pool of existing end user customers; however, these have many ranges of airframe sizes to offer products. As stated by one respondents, ''*usually new customers already fit within the scope of an existing product frames size*.'' The strong market position, highly focused on research and development, diversified revenues and wide-spread geographic presence, are the key factors influencing the strength of the D on sensing capacity and seizing capacity. In D, mid-range score on DC has been explained by the company's respondent from internal supply chain perspectives. *''The company is low volume production in comparison to* C *and* A. *Dynamic movement on projects usually entails a change in a new piece of technology, i.e. machine tool functionality however, additional cost are amortised against a relatively low volume of products.*

NPD projects that are born out of engine efficiency improvements (majority are for aerospace), may change during the CAD modelling or production trial phase, where design for manufacture is not 100% guaranteed until parts have started to be produced''. As table 2 and figure 5 show, sensing and seizing capacity scores are better than C. This is explained by the respondent that *''as volumes are fairly stable in aerospace, in the project phase the lead-time between concept and mass production is lengthy. As new products tend to give significant efficiency benefit to the engine and given the lead-time and associated costs of developing a new product, there are many stringent phases to the trials processes to ensure the project deliverables are achievable''.*

According to the Table 2, the E company has achieved the average performance score of 49% that shows the low level of its DC but higher than C's level of DC. This can be explained by the strength and weakness of E. The level of the broad portfolio of products and services and the continued focus on R&D for the company are lower than other companies. The weaknesses of E are customer concentration and increased business risk, making the company low on DC level compared with other selected companies. However, the company has a strong focus on R&D which strengthens the sensing capacity level. The company's focus on customer trust, collaboration, and execution has allowed them to increase opportunities by addressing an increasing portion of capital spending and delivering enhanced value to customers, employees, and stockholders. This increases the level of seizing capacity in the company. Finally, E company needs to focus more on the knowledge sharing routines, governance mechanism and autonomy in order to increase the level of reconfiguration capacity. However, the company's success depends on rewarding partnerships the company has built with its customers and suppliers, the achievement and commitment of employees worldwide, and the valued support of stockholders.

Figure 5 shows that A is the 1st best which can be explained by the evidence collected from company that *''Not surprised by the outcome with* A *scoring highest, as mentioned above* A *have full time departments managing NPD and the flexibility / dynamic capability during NPD projects has more agility than* C *and* D. *In terms of the product, this also lends itself to a more dynamic ability*

Figure 5. Belief distribution assessment of selected companies on DC



in terms of testing when compared to C *and* D. *The validation of life cycle longevity of product in a Turbo Charger can be simulated in a matter of days however; testing the end product of an actual vehicle of gas turbine engine requires significant cost and resource to test''. ''Full time teams set up to work on NPD projects, dynamic capability for NPD / NPI projects is standard work within Turbo Charger business''.*

According to the Figure 5, C is the 3rd best but also highest worst score. As previously mentioned, *''*C *tend to stay rigid with a project. They can bring a product to market quickly once the supply chain is set, but the dynamic capability is low''. ''No surprise at this score* C *and the automotive industry tend to stick with the NPD project, with only minor changes such as software upgrades and slight dimensional tolerancing changes.* The level of flexibility within the project is less than A or D, as the products are interlinked with multiple external suppliers. *''*C *tend to regard a dynamic change with NPD as a new project, rather than flexibility within a current project''.*

As illustrated in the Figure 5, D is the 4th best but highest average evaluation. As highlighted by one of respondents, *''alternatives considered within* D *that drive dynamic capabilities are at a manufacturing level rather than a component level. The design is the design and will not be changed quickly. The manufacturing parameters, methods and processes can have alterations based upon results during the NPD project at trial production phases. So I would concur that D rank in between* A *and* C *on this analysis''. ''Secondments teams set up for NPD projects. Ability to change a project mid-flow is difficult because of the design integrations (effects on other components) and additional costs are amortised over a relatively low volume of components, therefore payback period is protracted''*

4.3 Sensitivity Analysis

Here, the sensing capacity is given the lower weight of 3.80 compared with seizing capacity and reconfiguration capacity weights. In fact, the sensing capacity is very important for the companies and this can be accounted as the most important dimension of DC for improving performance of companies. For this purpose, as the weights for the sensing capacity increase from the given weight (3.8) to much higher weight, then the average performance score for two larger companies such as D and E increase significantly. This means that the area of improvement for these European and American aviation manufacturing sectors needs to be considered based on the management practices that relate to the sensing capacity. As the relative weight for seizing capacity change from the given weight of 4 to much higher values, no significant changes occurred on the average performance score of alternatives on DC. As the relative given weight of 4 for reconfiguration capacity increase to much higher values, the average performance score of the two selected companies of D and E decrease significantly. This means that the area of knowledge sharing, governance mechanism and autonomy need to be strengthened. Based on the relative importance of the criteria obtained from the relevant respondents, the key areas that need to be focused upon are search for new technology in sensing capacity, building trust in seizing capacity and autonomy in the reconfiguration capacity.

5. CONCLUSION

The study developed a comprehensive framework for the assessment of DC by using the multiple case studies in automotive sectors. The framework was developed and validated by interviews with senior managers and chief executives and support from related documents and literature. The research framework was developed based on specific objectives, concerns, and characteristics of the automotive companies against managing NPD projects. The MCDA method and results can help managers to gain more insight and knowledge about why failure rate is so high in NPD projects. The presented DC model is powerful for managing NPD projects, project overruns, and defect rates. The method can provide managers with a useful tool with which to assess their company's strengths and weaknesses in regard to the performance level of sensing capacity, seizing capacity and reconfiguration capacity. The validated MCDA framework can help purchasing and R&D managers to leverage the resources

Figure 6. The effects of change weights of sensing capacity on DC

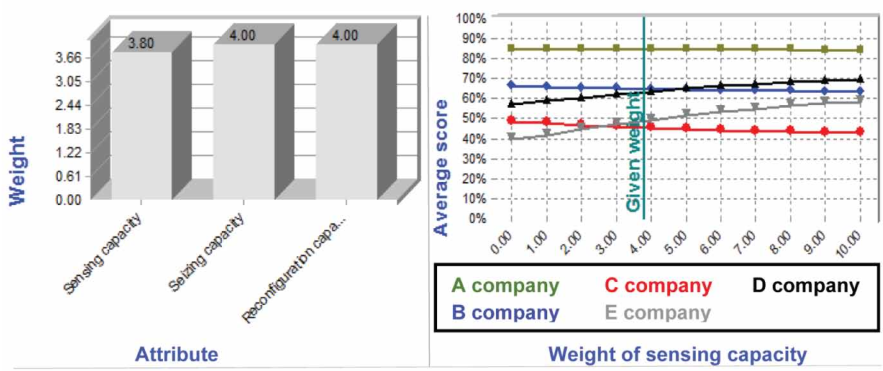


Figure 7. The effects of change weights of seizing capacity on DC

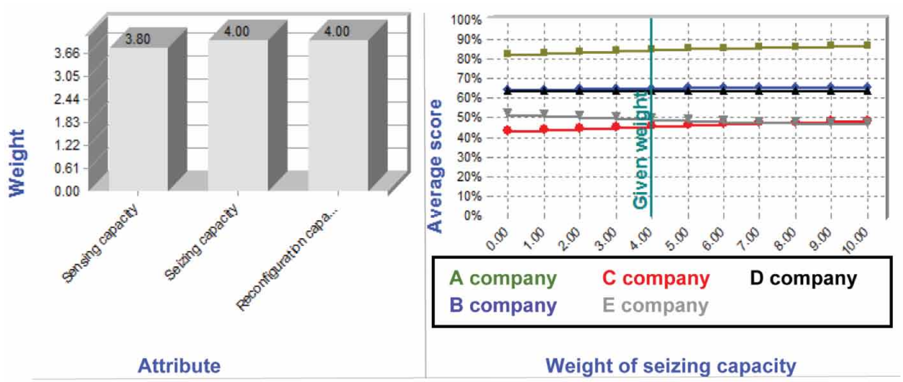
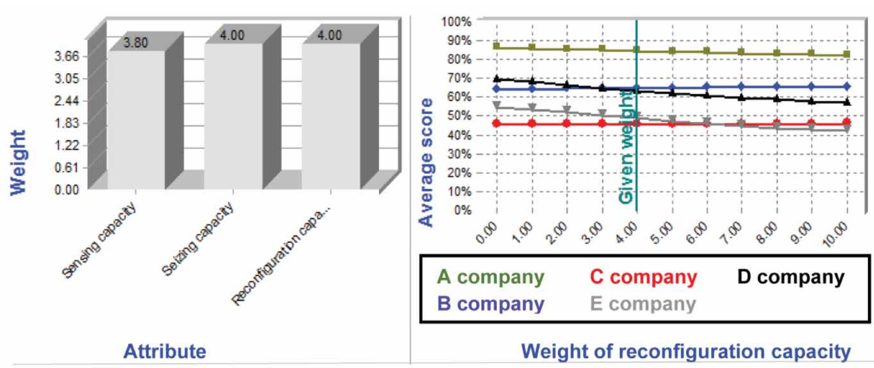


Figure 8. The effects of change weights of reconfiguration capacity on DC



and knowledge of their suppliers and customers for managing NPD projects. The MCDA model on DC can also engage them to integrate suppliers into NPD projects effectively, efficiently and proactively. The outcome of the MCDA models on DC can enable managers to identify the areas of improvement for managing NPD projects, and achieve sustainable competitive advantage. This study also attempts to enhance knowledge on how the success of manufacturing companies in conjunction with NPD projects/programmes can be improved. The important managerial implication is the ability to let senior managers access, select, integrate and coordinate emergent latest technological knowledge into existing product and process knowledge though micro-foundations of DC.

This study proposed the DC assessment models as a holistic operationalized approach that can assist companies to explain how they organize to exploit their resources via supply chain linkages to deliver competitive advantage, and also how competitive advantage is created and sustained, especially in recent rapidly changing business environments. The research findings provide several guidelines for managers, particularly in the automotive industry, for the effective planning and execution of their NPD activities. This study provides managers with a useful tool with which to assess their company's strengths and weaknesses in regard to the three DC components. The proposed measures provide a basis for determining where additional investment should be made to improve a company's DC components for the purpose of performance improvement. Managers can creatively leverage their companies' DC components by conceiving different ways to integrate these DC components.

The analysis of companies' strengths and weaknesses can also be done logically through the ER model and the hierarchical framework. A logical process of performance analysis can help managers identify the area of improvement. It also facilitates decision making relating to DC assessment. The models can be applied to any cases of multiple criteria assessment regarding DC development and firm performance at different context. The development of DC through supply chain collaboration which is aggregated via a multidimensional framework, can lead senior managers of manufacturing companies to leveraging the resources and knowledge of their suppliers and customers. One of the main achievements of this study is the applicability and validity of the two generic multi-dimensional DC and NPD performance assessment models for manufacturing companies to conduct performance self-assessment.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

The DC assessment frameworks that are developed and tested in the manufacturing companies are the platform and first step for performance analysis and improvement of manufacturing companies. Further research needs to be conducted to consider DC assessment from all aspects of social, technical and environmental dimensions. The comprehensive and multi-dimensional aspects of DC help companies to make better decisions for managing NPD projects. It is important to consider much wider communication with different R&D managers and purchasing managers who have knowledge in NPD projects and SC. Due to the importance of DC in performance assessment for companies at different levels, including strategic, tactical and operational levels, respondents can be grouped into higher and lower levels of position and responsibilities. In future, performance self-assessment should be conducted at large scale in the sense that more respondents with knowledge in DC performance assessment should be included in DC survey to achieve more robust and accurate results for examining the complex interrelationship between DC. In addition to this, the relationship between micro-foundations of DC should be tested through large scale data collection and analysis using statistical methods.

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