Application of vendor rationalization strategy for manufacturing cycle time reduction in engineer to order (ETO) environment

A case study

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Abstract

Purpose – The purpose of this paper is to demonstrate the application of vendor rationalization strategy for streamlining the supplies and manufacturing cycle time reduction in an Indian engineer-to-order (ETO) company. ETO firms are known for a large number of vendors, co-ordination hassles, rework problems and its impact on cycle time and operational excellence.

Design/methodology/approach – The research demonstrates the case-based application of Kraljic's matrix for supply and leverages items, on-the-job observations, field visits, discussions and analysis of supplies reports.

Findings – The study guides on the rationalization of supplies and the necessary strategic alignments that can significantly reduce supply risk, costs, manufacturing and delivery cycle time along with co-ordination hassles. The study depicts the challenges of ETO environment with respect to supplies, and demonstrates the effectiveness of vendor rationalization application for the case company and weaknesses of commonly practiced vendor management approaches.

Practical implications – To be competitive, companies should rationalize supply items and vendors based on the nature of items and their subsequent usage by applying Kraljic's matrix-based classification. The immediate implication of vendor rationalization is misunderstood as reducing supply base, but it does much more and includes review of supplies, nature of items and strategic alignments, leading to win-win situation for company and suppliers.

Originality/value – For the rationalization of supplies, while procuring and dealing with vendors, executives should envisage engineering nature of components, considering cross-functional requirements and integration of components in context to ETO products/projects environments. There is a dearth of studies focusing on vendor rationalization aspects in ETO setups in fast-developing country context.

Keywords Supplier evaluation, Manufacturing management, Strategy, Value chain, Cycle time

Paper type Case study

1. Introduction

The management of manufacturing has undergone sea changes in the last decade posing severe challenges to the way manufacturing is understood, managed, strategized and practiced. Three of the most notable changes are: sustainability and green pressures; increased levels of complexities to handle manufacturing and delivery cycle time; and growing economic and social uncertainties which cannot be overlooked or ignored, but need to be addressed. This becomes even more challenging in context to complex production environments like engineer to order (ETO), more so in a developing country context (Kumar *et al.*, 2018; Riis *et al.*, 2007). India with its diversities and large geography poses the major challenge of supplies of the components and products in a cost-effective manner. It is also

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noticed that the nature, type and variety of products being manufactured in India are also influencing the very nature of manufacturing management (Seth *et al.*, 2017).

Due to the increasing variety with growing complications, customization pressures and needs to embrace technology advancements, industries are shifting toward ETO production environments. Managing and handling complexities in a proficient manner can create strategic differentiation for a company. The current offer-make-market paradigm also demands customized products that only could be carried out by means of complex manufacturing systems like ETO. Therefore, the trend toward these types of manufacturing systems is clear. The challenge, as well as a necessity, is how to achieve an efficient and competitive manufacturing setup by attacking manufacturing cycle time (MCT) from vendor rationalization point of view in this environment influencing both manufacturing and supply chain management (Mello *et al.*, 2015a, b). This study attempts to address this challenge in context to an Indian company, operating under ETO environment.

One of the important needs of manufacturing management research today is to reduce the MCT; therefore, vendors, who can contribute toward this, become very important to the organization. The subject is equally important for those companies as well, which depend a lot on the vendors. In order to control the MCT, traditionally the vendors are selected based on their capabilities like manufacturing facilities, technical skills and financial stability (Kant and Dalvi, 2017). Later, they are constantly rated based on their performance in terms of price, quality and delivery. The ones rated bad are either discontinued or provided technical support/expertise to improve. This age old approach of dealing with vendors is treated as accepted practice of doing business and handling manufacturing management, without considering the challenges of ETO environment and nature of supplies.

This paper applies a different approach for the supplies of components, parts and modules, and suggests a vendor rationalization-based approach for reducing MCT under ETO environment. Vendor rationalization generally is referred as an approach of reducing total number of vendors to cut costs and minimize co-ordination hassles, and thus introducing supply efficiency so that vendor base can further be refined, optimized and can be made more effective.

With respect to vendors' management and allied areas in ETO manufacturing contexts, three important gap areas are noticed. It is noticed that the majority of vendor management approaches mostly discuss about vendor selection and evaluation aspects and do not cover vendor rationalization requirements. These vendor management studies focus on prioritization aspects only, and assume that "prioritization of vendors" can alone handle supplies-related challenges, which is not totally true. Majority of these studies are geared according to mass production systems, as reflected in a number of published research works and review studies (Gosling *et al.*, 2015; Agrawal and Nahmias, 1997; Narasimhan *et al.*, 2001; Ho *et al.*, 2010; Mello *et al.*, 2015a). The manufacturing- and supplies-related challenges in ETO are fundamentally different than mass production systems. Other noticeable problem with these studies is that nature and complexities of individual components are rarely taken into consideration while discussing the vendor management approaches.

Hence, an urgent need is felt for the research study like ours, discussing vendor rationalization application for helping in the reduction of MCT, as well as costs within the scope of ETO systems (Persona *et al.*, 2004; Oettmeier and Hofmann, 2016; Matt, 2014; Seth *et al.*, 2017). The study demonstrates the application of this approach for MCT reduction applied to an Indian manufacturing unit PQR (name changed due to confidentiality reasons) located in Mumbai, operating under ETO environment. Accordingly, the scope of the work is restricted to this unit (case company). The research objective raised for the study is as follows:

- How to apply vendor rationalization in context to the case company operating under ETO environment to strategize and leverage supplies of components, items, modules and parts in order to achieve reduction in MCT?

The rest of the paper is organized as follows.

Section 2 discusses literature review organized in five sections, indicating research gap areas and justification of chosen approach. Section 3 explains the research methodology for the study. Section 4 outlines the weaknesses in the current approaches in Indian contexts. Section 5 outlines the proposed vendor rationalization scheme based on Kraljic's matrix. Section 6 discusses case study details for application. Section 7 discusses strategic benefits realized after application. Section 8 covers the findings and conclusions. Section 9 discusses limitations and future scope of the study.

2. Literature review

Scholars have suggested a number of approaches for MCT reduction considering ETO challenges. These approaches include customer order decoupling point (CODP), modularization, theory of constraints, paired cell overlapping loop of cards with authorization, constant work in process, quick response manufacturing, value stream mapping, postponement, Kanban system, standard work approach, process mix with family analysis, product variety funnel, mixed pull system (high, medium and low runners) and work content graphs. For an overview, please refer Araya (2012) and Prakash and Chin (2014). The study focuses on vendor rationalization in ETO environment, and accordingly the literature is organized into five subsections. First section outlines the peculiarities of ETO environment and challenges with respect to supplies. Second section discusses an overview of vendor management and approaches. Third section discusses the studies in the areas of vendor rationalization approaches. Fourth section discusses the research gap areas and fifth section justifies the chosen approach.

2.1 Engineer-to-order (ETO) environment and supplies-related challenges

Scholars like Hicks *et al.* (2000), Olhager (2003), Gosling and Naim (2009), Matt (2014) and Seth *et al.* (2017) discuss their observations and views about ETO environment and associated challenges.

ETO environments are unique and are characterized by product complexities and customer involvement in design and high levels of process and product variations. One can easily observe multi-leveled bill of materials (BOMs) with deep product structures, variations in machine times and routings, and parallel and independent working for parts/sub-assemblies with low volumes. Each order involves a lot of customer interactions, clarifications, approvals and is mostly treated as a project, involving intermediate testing, design and development challenges depending upon requirements. Design, delivery speed, variety and flexibility are typical order winners and CODP is typically located at the start of production. The usual key strengths of ETO companies are design, engineering, manufacturing, assembly (from engineering point of view) and tendering, procurement and commissioning (from commercial and support point of view) (Seth *et al.*, 2017; Birkie and Trucco, 2016).

Scholars (Dallasega *et al.*, 2015, 2017), while investigating ETO projects in the areas of engineering and construction, observe unique challenges regarding supplies and vendors. They observe that vendors in ETO situations assist in engineering, fabrication, installation and supply parts on site as per customer order. The difficulties they face is that ETO components are fabricated and delivered to the site as per static master schedule (MPS) and not as per real demand. As MPS remains static and is not updated periodically, it does not capture deviations throughout the supply chain. It ultimately affects both customers and vendors and adds to cycle time. In construction-related ETOs, they identify that time schedules used for tendering process are not sufficiently detailed and ultimately affect co-ordination at work sites. Other peculiarity they observe is high unpredictability of future events which alters the requirements of projects and demands re-planning and rescheduling of supplies influencing the cycle time.

Similarly, scholars (Sjøbakk *et al.*, 2015) attempt the characterization of supplies in ETO and caution about the conventional performance measurement schemes. They also propose their scheme of performance indicators for ETO-related supplies and observe that supplies and vendors need to be carefully handled.

There are many versions and views about ETO environment and accordingly the characterization also varies which influences the supply of parts, materials, modules, components and sub-assemblies and interpretations of the difficulties at both company's and vendors' end (Gosling and Naim, 2009; Javadi *et al.*, 2016). Broadly these versions, definitions and views influencing characterization can be classified into three broad categories, with some overlaps:

(1) Based on the location of CODP (also known as order penetration point), which is treated as a signaling buffer point against demand fluctuations, influencing supply schedule and manufacturing processes while reacting to uncertainties in customer orders. Naturally, CODP separates upstream and downstream supply chains. Upstream supply chain responds to forecasting and includes supply of parts, items and operations, and downstream supply chain responds directly to customer order (Olhager, 2003, 2010; Wikner and Rudberg, 2005; Gosling and Naim, 2009).

(2) Based on "customization and standardization," accordingly it can be pure customization or tailored customization in varying degrees. The overall approach is to treat ETO as a modified case of make to order considering design and production needs, along with standardization and customization requirements of the business covering manufacturing and supply chain management (Lampel and Mintzberg, 1996; Mason-Jones and Towill, 1999; Rudberg and Wikner, 2004; Wikner and Rudberg, 2005). Therefore, research studies like Yang and Burns (2003), Yang *et al.* (2004) and Seth and Panigrahi (2015) are not only postponement studies but also support ETO in terms of customization and standardization of parts/modules/packaging/components needed for product.

(3) Based on treating ETO as project or projectized environment and treating each product as unique, requiring project-based challenges and specific requirements. While first view makes use of "CODP" as central theme, second view makes use of "customization and standardization" logic and third view incorporates "unique product or project situation" which may even be a construction of a ship project or a new product development (Gosling *et al.*, 2015; Yang, 2013; Rahman Abdul Rahim and Shariff Nabi Baksh, 2003; Hicks *et al.*, 2001; Olhager, 2003).

One can notice that mostly manufacturing and supply chain management are dealt in tandem in context to ETO. Similarly, one can also observe that there is a considerable overlap between the views, which influences interpretations and may complicate the characterization and handling of supplies, vendors and their management. Following supply characteristics duly supported by literature, as shown in Table I, can be summarized influencing vendor management in ETO.

2.2 Vendor management covering criteria, methods and cost-based procurement models: selected studies

Scholars (van Weele, 2014; Monczka *et al.*, 2009) argue that for vendor rationalization, one needs to know both vendor management models and purchasing cost models.

The first (vendor management) area mainly covers criteria and methods used for vendor evaluation and prioritization requirements. Second area focuses on procurement aspects, accounting details and covers cost-based approaches. Authors are covering both using select studies, as a large number of studies are available in both areas.

S.No.	Supply characteristics	Literature support
1	Project-/Product-specific purchasing of parts, modules and components, as the percentage of components and items cost in context to total cost of the product is very high	Birkie and Trucco (2016), Yang (2013), Rahman Abdul Rahim and Shariff Nabi Baksh (2003), Seth *et al.* (2017), Hicks *et al.* (2000, 2001), Javadi *et al.* (2016), Mello *et al.* (2015a, b)
2	Mix of standardized and customized supply of components varying from low to medium volumes	Rahman Abdul Rahim and Shariff Nabi Baksh (2003), Mason-Jones and Towill (1999), Matt (2014), Olhager (2003), Rudberg and Wikner (2004), Gosling and Naim (2009)
3	Outsourcing is encouraged as the key strengths of the company are design capabilities, engineering, assembly, tendering, procurement and commissioning	Mello *et al.* (2015a, b), Matt (2014), Gosling *et al.* (2015), Olhager (2003, 2010), Hicks *et al.* (2000, 2001), Rahman Abdul Rahim and Shariff Nabi Baksh (2003)
4	Large vendor base and multi sourcing	Wikner and Rudberg (2005), Gosling and Naim (2009), Hicks *et al.* (2001), McGovern *et al.* (1999), Mello *et al.* (2015a, b)
5	High dependence on vendors due to highly customized or very specific type components	McGovern *et al.* (1999), Olhager (2003), Gosling and Naim (2009), Hicks *et al.* (2000), Javadi *et al.* (2016), Sjøbakk *et al.* (2015)
6	Supplier relationships vary and are complicated	Mello *et al.* (2015a, b), Olhager (2003), Rudberg and Wikner (2004), Gosling and Naim (2009), Hicks *et al.* (2001)
7	Purchase of parts and items is initiated only when advance money (part payment) from the client is received	Matt (2014), Yang (2013), Rahman Abdul Rahim and Shariff Nabi Baksh (2003), Hicks *et al.* (2000), Birkie and Trucco (2016), Mello *et al.* (2015a, b)
8	Parts or sub-assemblies or purchased items from vendors represent a large proportion of the contract value	Mello *et al.* (2015a, b), McGovern *et al.* (1999), Yang (2013), Wikner and Rudberg (2005), Rudberg and Wikner (2004), Olhager (2003), Sjøbakk *et al.* (2015)
9	Vendor co-ordination efforts and costs are very high due to design- and process-based clarifications and to accommodate changes in specifications	Mello *et al.* (2015a, b), McGovern *et al.* (1999), Gosling and Naim (2009), Hicks *et al.* (2000, 2001), Olhager (2003, 2010), Gosling *et al.* (2015), Dallasega *et al.* (2015, 2017)

Table I. Supply characteristics in ETO influencing vendor management

Reader may refer one recent paper by Talluri *et al.* (2013) regarding an overview of vendor criteria-, methods- and cost-based approaches including the most commonly used total cost of ownership (TCO). Similarly, for the comparison between TCO and an important vendor evaluation method analytical hierarchy process (AHP), one may refer Bhutta and Huq (2002).

The studies like Palanisamy and Abdul Zubar (2013), Koul and Verma (2011) and Ghodsypour and O'Brien (1998) claim that in most of the manufacturing industries, the cost of components, items, raw materials and parts can reach up to 70–85 percent of the final product cost. Similar views are expressed by Mello *et al.* (2015a, b), Sjøbakk *et al.* (2015), Yang (2013) and Gosling and Naim (2009) who after considering the characterizations of ETO argued that the percentage procurement cost of components, modules and other items is very high in context to total cost of product. If planned intelligently, the procurement/acquisition of items can offer strategic advantages to company and can have a significant impact on cycle time also.

Please refer Seth, Nemani, Pokharel and Al Sayed (2018), which covers a large number of studies including both vendor management criteria and evaluation methods. This study reports that for vendor evaluation criteria and methods, seven journal papers (Weber *et al.*, 1991; De-Boer *et al.*, 2001; Wang *et al.*, 2009; Wu and Barnes, 2011; Ho *et al.*, 2010; Agarwal *et al.*, 2011; Chai *et al.*, 2013) can be referred. Same study highlights that while discussing vendor management, majority of the researchers cover both criteria and evaluation methods. For example, the studies by Ho *et al.* (2010) and Wang *et al.* (2009) cover both criteria and evaluation approaches and indicate that vendor evaluation is a multi-criteria decision-making (MCDM) problem. The study by Ho *et al.* (2010) reports that commonly used criteria are quality, price and delivery lead time.

The search for appropriate criteria was first reported by Dickson (1966), who covered 23 criteria of vendor evaluation. Second widely quoted study Weber *et al.* (1991) concluded that for vendor management, quality, deliver, price, location and production-capacity were most common among other criteria. Similarly, the study by Ellram (1990) offered four groups for criteria-financial issues, organizational culture and strategy, technological capabilities, and a group of miscellaneous factors including risks management. Researchers like Verma and Pullman (1998) study the trade-off between on-time delivery, quality, cost and conclude that managers treat quality as the most significant vendor attribute, followed by delivery and cost. Bhutta and Huq (2002) advocated criteria like quality, manufacturing costs, technology and services for vendor evaluations. In Indian context, survey-based study about vendor management inventory practices by Borade and Bansod (2010) concludes that the nature of criteria and issues for small and large industries is different and vendor management needs to be explored more. A recent Indian study by Kant and Dalvi (2017) lists about 129 vendor management criteria and identifies that the most important criteria are quality, on-time delivery, cost, performance, technical capability and flexibility.

Similarly, it will be important to consider select studies covering vendor evaluation approaches. Reader may refer studies like Seth, Nemani, Pokharel and Al Sayed (2018), Koul and Verma (2011) and Palanisamy and Abdul Zubar (2013) covering a variety of vendor evaluation approaches. For vendor evaluation approaches exclusively in project/ETO environment, reader may refer a recent review study by De Araújo *et al.* (2017). A large number of vendor evaluation studies are available like Koul and Verma (2011) that made use of fuzzy AHP for evaluation purpose and Motwani *et al.* (1999) that discussed vendor evaluation in context to developing countries. On the other hand, Yadav and Sharma (2016) used AHP for vendor selection model in context to automobile industries. Similarly, Bali and Amin (2017) used both AHP and mathematical programming for vendor evaluation and selection requirements.

After carefully delving in vendor selection and evaluation methods review studies, one notices that in the name of vendor evaluation, many scholars suggest the use of mathematical and operations research-based models and MCDM approaches and while doing so they usually avoid costing- and accounting-based inputs which are must for procurement.

From procurement point of view, a large number of costing models are available. Most important among these models are activity-based costing (ABC), TCO, cost-ratio approach, landed cost model and life-cycle costing (LCC). For an overview of these costing models, please refer van Weele (2014), Monczka *et al.* (2009), Magnuson and Bäckström (2015), De-Boer *et al.* (2001) and Ellram and Siferd. ABC costing approach assigns and monitors cost to those activities, which consume resources and/or services for the completion of product/project. It thus helps in tracing resource consumption and costing of final product/project and avoids haziness associated with overhead/indirect costs. According to Ellram and Siferd, ABC is prerequisite to TCO. It is due to the fact that TCO also makes use of activities to compute final incurred cost.

Among all procurement cost models, TCO promoted by Ellram (1990) is the most popular choice among users. TCO is defined as a model, which includes all the costs associated with the acquisition and use and even includes maintenance of product/project over its life-cycle. According to Ellram and Siferd, it includes six cost driving activities associated with quality, price, management, delivery, service and communication. Later, their TCO work was extended by Ferrin and Plank (2002).

Not much literature is available to discuss cost-ratio model (van Weele, 2014). It was popularized by Timmerman (1986). He used cost-ratio concepts to evaluate and compare different vendors. He treated the cost of doing business with a certain supplier as penalties that raise the initial procurement price and thus make that supplier less attractive for the purchase.

Another popular model is landed cost model which was promoted by Young *et al.* (2009). This study makes use of Ellram's idea of grouping cost activities based on pre-transactional, transactional and post-transactional activities. They limited their landed cost modeling approach only to transactional phase. An important vendor management model is LCC which is often misunderstood and mixed with life-cycle assessment. The later one concerns with the evaluation of the environmental impact/performance of a product, whereas former one has economic focus. LCC can be effectively used for vendor management while considering the selection of various options that impact both pending and future costs. For more details, please refer Korpi and Ala-Risku (2008).

Thus, while considering vendor rationalization, one should contemplate both vendor management and purchasing models based details along with the clear understandings about requirements and inputs from supply chain management, performance management and manufacturing management, which depend upon the type of environment. This will help in and facilitate appropriate grouping of the components based on the cross-functional requirements.

The scholars like Luzzini *et al.* (2014) also support our views and argue that while discussing vendor evaluation systems, theses inputs should also be used for some kind of grouping rather than blindly following mathematical models for prioritization.

Next sub-section discusses vendor rationalization along with segmentation and applications of Kraljic's matrix.

2.3 Vendor rationalization along with segmentation and application of Kraljic's matrix

Vendor rationalization is not a new concept. It was first advocated by Deming when he discussed the basics of negative quality, excessive variations, high cycle time and cost implications of maintaining a large vendor base. Deming argued that the strategic objectives of quality, cost and variations reduction can only be achieved if the company knows how to manage smaller vendor base (Talluri *et al.*, 2013). Thus, vendor base reduction and allied needs for the segmentation of vendors were strategically recognized. For a detailed review on ten segmentation approaches, reader may refer Rezaei and Ortt (2012), and for extensions in Kraljic's matrix, reader may refer (Hesping and Schiele, 2015, 2016). This requirement of grouping or segmentation was addressed in three directions (three different methods and their combinations), as pointed out by Rezaei and Ortt (2012). These methods are: process method, involvement method and portfolio method. The process method was promoted by Parasuraman (1980). His approach of grouping is based on four steps: identify the key features of customer segments, identify critical vendor characteristics, choose the relevant variables for vendor segmentation and identify the vendor segment. As Parasuraman (1980) did not discuss "specific variables" for his method, his work was treated as conceptual. Lately, his work was extended further by Rezaei and Ortt (2012). But Parasuraman was clear in his approach that after customer segmentation, the next logical step would be vendor segmentation.

Involvement method was promoted by Dyer *et al.* (1998). Their approach was based on the comparisons between vendor–automobile companies' relationships in Japan, the USA and Korea and was developed on the basis of outsourcing strategies segmentation based on "relationships." This team of researchers was clear that firms first should decide about their core competencies and then decide about core activities. Therefore, resources allocation which supports core activities is strategic and which does not should be treated as a non-strategic resource. Obviously, the level of involvement with vendors will decide the "strength of relationship as single variable," based on strategic/non-strategic supplies. Earlier about involvement method, Cox (1996) discussed about core competencies and relationships segmenting the vendors. On the other hand, Dyer *et al.* (1998) made this relationship-based variable as explicit.

Portfolio method was promoted by Kraljic (1983) and was based on two variables, "profit impact and supply risk." Kraljic defined the profit impact of a supply item/component/module in terms of quantity purchased, the percentage of total purchase cost or the impact on final product quality and growth in business. On the other hand, for supply risk, he commented that it is assessed in terms of availability and number of vendors, competitive demand, make or buy opportunities, storage risks and substitution possibilities. Considering these two variables, he proposed a portfolio comprising of four categories: strategic items (supply risk: high; profit impact: high), leverage items (supply risk: low; profit impact: high), non-critical items (supply risk: low; profit impact: low) and bottleneck items (supply risk: high; profit impact: low). Table II represents the major studies and applications without extension reported in literature.

2.4 Literature gaps

- Vendor management mostly remains confined to evaluation criteria and evaluation methods based on mathematical/operations research studies which primarily focus on MCDM-based prioritization. To make the scenario even more challenging, some scholars use MCDM hybrids both in context supply chain management and manufacturing like Luthra *et al.* (2017) and Yadav *et al.* (2018a, b) to name a few, so the subject treatment remains complex and mathematical, which centers around the usage of MCDM-based prioritization. Unfortunately, while carrying out this exercise, the inputs from purchasing management, supply chain management and performance management are not taken into account, which influence supplies and vendors both. Similarly, these inputs also influence manufacturing management and cycle time.
- Majority of the conventional studies focus on vendor prioritization and do not discuss segmentation or grouping of vendors-based requirements. This indicates that researchers believe that "prioritization only" is more than sufficient for vendor management and it will directly or indirectly take care of grouping of vendors, which is not true. In comparison to MCDM-based evaluation methods, relatively much less studies are available which discuss about the subject of vendor rationalization and advocate segmentation requirements. It may be highlighted that still many grouping schemes and formats (like, Hesping and Schiele, 2015, 2016; Rezaei and Ortt, 2012) are yet to be explored, applied in context to different manufacturing environments.

S.No.	Studies and application areas	Literature support
1	Survey-based study covering 107 sourcing projects validates the superiority of Kraljic's matrix and empirically establishes the usage and extensions	Hesping and Schiele (2016)
2	State government's rural development department	Padhi *et al.* (2012)
3	Automobile company considering select items	Wagner *et al.* (2013)
4	Application by converting qualitative nature of matrix as quantitative one	Montgomery *et al.* (2018)
5	An oil company operating under ETO where logistics facilities are not developed	Gelderman and Mac Donald (2008)
6	Hospital procurement	Medeiros and Ferreira (2018)
7	Construction sector procurement operating under project/ ETO environment	Ferreira *et al.* (2015)
8	Elevator manufacturers under ETO environment	Lee and Drake (2010)
9	Facility management	Jensen (2017)
10	Two automotive and vehicle making companies in Europe	Nellore and Söderquist (2000)

Table II.
Major and select applications of Kraljic's matrix

- According to van Weele (2014), vendor management models center around product/process requirements and focus on functional aspects, whereas purchasing models center around quality assurance/company requirements and address cross-functional aspects. In ETO and project setups, it is always advantageous to take care of both aspects along with the details about nature of the components, and other supply items in context to product/project and subsequent integration/commissioning requirements. Conventional vendor management models do not serve the purpose of manufacturing and supply chain integration requirements and also do not guide about the grouping or segmentation of components to facilitate rationalization. Similarly, on the other side, the practical difficulty with purchasing models requires lot of data and accounting efforts and also lacks in integration aspects, which are important requirements from manufacturing management point of view and influence cycle time.
- Moreover, in most vendor evaluation studies, the nature of supplies, parts, components and its influence on manufacturing, supply chain, purchasing-based requirements and performances are not addressed explicitly. The nature of manufacturing environment-based considerations influencing the supply and nature of supply is also seldom considered in MCDM-based vendor evaluation studies. So practically, in majority of studies, "vendor rationalization" and logical grouping of vendors seem to be missing, as the nature of environment and its challenges are not taken into account.
- Despite a number of supply-related challenges reported by scholars like Mello *et al.* (2015a, b), Gosling and Naim (2009), Sjøbakk *et al.* (2015), Hicks *et al.* (2000, 2001) and Olhager (2003, 2010), not many studies are available which exclusively discuss the supplies, their nature and vendor rationalization requirements in context to ETO environment both in developed and fast-developing country perspectives like India.
- Further, the segmentation- or grouping-based studies including Kraljic's matrix applications-based studies are hardly available in Indian contexts. Researchers and practitioners expect more application-oriented studies from an important and one of the fastest growing economies of the world, which is sharply emerging as a manufacturing and sourcing base for the world as a whole (Mathew *et al.*, 2002; Padhi *et al.*, 2012; Seth and Tripathi, 2005, 2006; Seth *et al.*, 2016). Similarly, even in the application areas of Kraljic's matrix, there is a dearth of applications in ETO environment.

2.5 Justification for the choice of Kraljic's matrix for vendor rationalization in ETO

The subject of vendor management has undergone sea changes. It cannot be practically dealt using MCDM/operations research-based vendor prioritization and evaluations approaches alone. These approaches lack in cross-functional integration requirements, inputs from purchasing management and do not consider the engineering nature of the components which are important requirements for ETO/project environments influencing cycle time and operational excellence. Vendor management should be handled in context to manufacturing environments and should be corrected/modified as per the needs of environments. To realize real savings and cycle time reduction, item type, its logical grouping and its integration requirements along with different cost drivers based on functional perspectives, components' purchase should also be acknowledged while handling any sourcing strategy. Vendor management requires cross-functional orientation and conventional MCDM and mathematical approaches lack in it. Therefore, through appropriate grouping arrangements, requirements from functions like purchasing, contract management, engineering, quality, manufacturing, manufacturing planning and supply chain management should be integrated to manage this exercise. Similarly, the engineering nature of the component like size, material, heat treatments, coatings, polishing and the criticality of dimensions also matters a lot, and at times it becomes a dominating requirement for vendor management and its rationalization. As in ETO and project environments, both engineering nature of the components and cross-functional consideration are a must which can be conveniently dealt by a segmentation approach like Kraljic's matrix.

Although approaches available in TCO family which were popularized by Ellram (1990, 1994, 1995) can be used, there are some practical difficulties associated with TCO family which are these approaches demand a lot of costing details and slow down the decision-making process, as pointed out by Bhutta and Huq (2002). Other practical difficulty with both MCDM-based vendor prioritization approaches and TCO family approaches is that the engineering nature of components is not considered, which is one of the critical requirements of ETO and project companies. Similar, was the situation in the case company, where the situation was demanding that the engineering nature of components should be considered to facilitate integration requirements in vendor rationalization exercise. In this situation, the logical choice for grouping approach was Kraljic's matrix.

Authors would like to propose Figure 1 justifying the need for vendor rationalization strategy using an approach such as Kraljic's matrix based on the inputs from van Weele (2014). The figure clearly indicates the position of Kraljic's matrix for rationalization purpose, facilitating the grouping of components based on cross-functional integration requirements.

3. Research methodology

Figure 2 represents the major steps of research methodology followed for this application-based study. The details about research team, systematic questioning technique for facts finding and *gemba-walks* are as under.

Realizing the complex nature of working in ETO environment, it was necessary to constitute a research team for facts finding, data collection, technical and managerial discussions. Accordingly, a team was formed comprising of vice president production, one senior production manager, one senior design engineer, senior manager procurement and materials planning, one vendor co-ordination engineer, head materials handling, materials manager, planning engineer and one industrial engineer along with the authors for the collection of necessary details and to carry out the study over a period of ten and half months. The experts identified for this team were very experienced. Each of them was

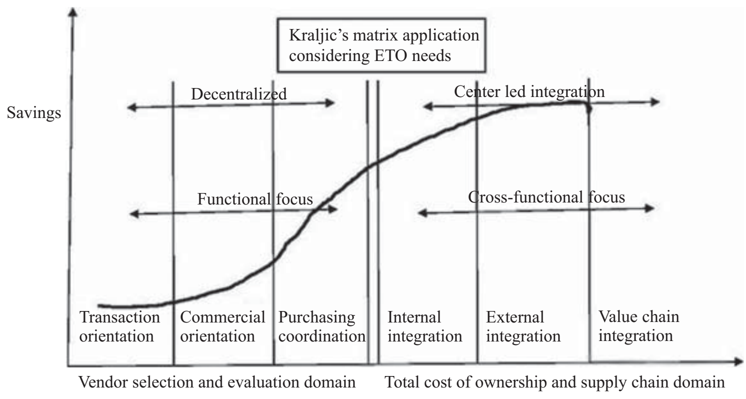

Figure 1.
Justification for the use of Kraljic's matrix for rationalization based on the requirements of project/ETO company

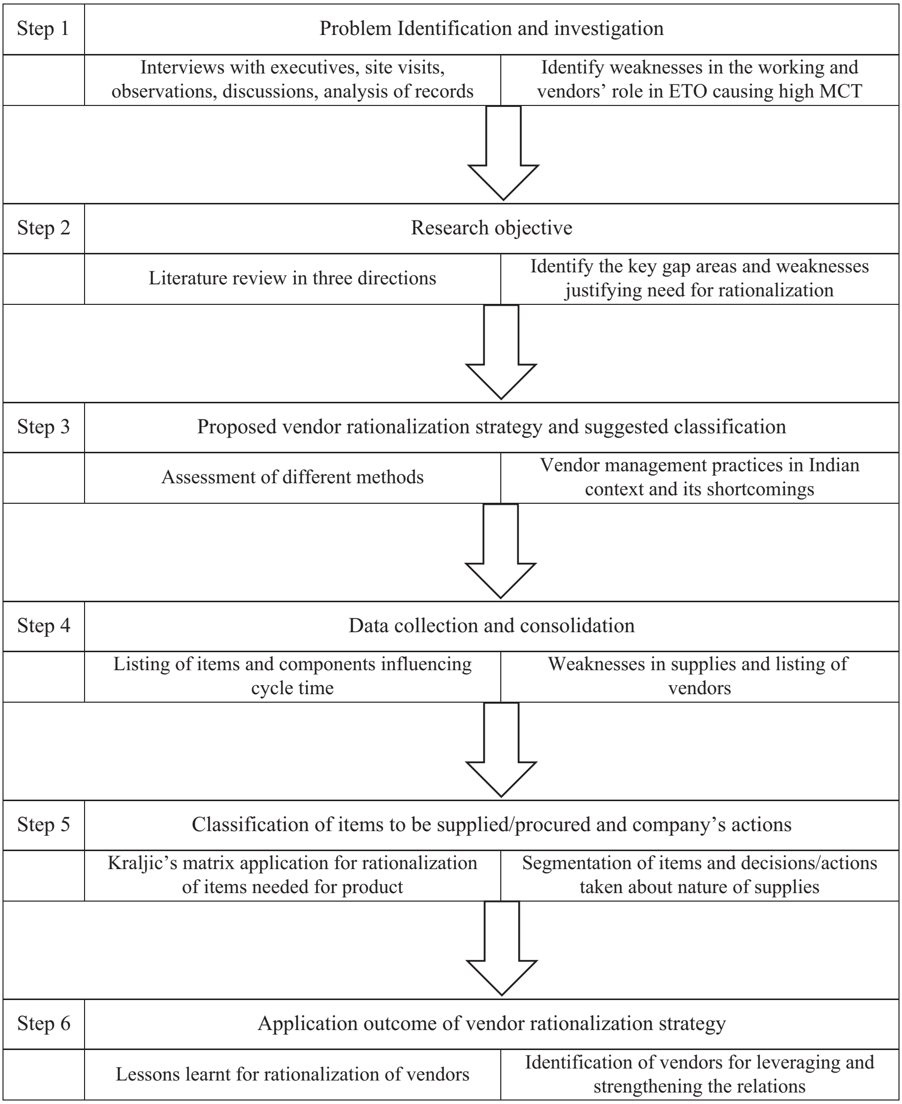

Figure 2.
Research methodology

having a relevant practical experience of more than 15 years and working for the case company for than eight years. Members were given free hand to include any other participants including vendors of the company, who possessed appropriate knowledge about the parts, fitment needs, operational challenges in their making and other workings as per the study needs. While deciding their roles and responsibilities, guidelines by Serrano *et al.* (2008) were taken into considerations.

The team initiated a series of discussions about major products, variants, operations done within the company and outside company, type of components and modules procured and various types of problems which indirectly and directly add various wastes and affect cycle time. Members also reviewed last few years' production data and "annual-build-plan" to understand both committed and anticipated orders and spill over (partial work and backlog orders) from the last year. Similarly, BOMs-related details were also gathered. Hard copy-based information in standard operating procedures and operations manuals was also referred and discussed. Like any industrial ETO product, the BOMs for the representative product (gravimetric weigh feeder) consists of more than 1,500 items for one model. However, if one considers the variants of the model, total inventory items in a large company can go up to 6,000 items also. The number also depends upon the amount of sub-contracting or outsourcing done as individual components or as sub-assemblies, like pulley sub-assembly, or electrical control panel. This number may increase further depending upon the attachments or fitments desired by the customer.

Members also carried out process reviews to examine and investigate the making method and existing shop-floor scenario. Along with process reviews, line observations and systematic questioning techniques (Seth and Rastogi, 2009), *gemba-walks* were also carried out to develop full understanding of the situation and facts about existing procurement, usage and other shop-floor practices and possibilities of improvement.

Regarding *gemba-walk* approach, scholars (Tyagi *et al.*, 2015; Seth *et al.*, 2017) comment that to fully understand a real life problem, one should visit the actual workplace multiple times and observe the impact of what is happening which causes difficulties and influences the working and cycle time. Coupled with *gemba-walks*, the research team also made use of systematic questioning techniques of 5W2H (why, what, where, when, who, how, how many/how much) and 5whys (asking why five times to find root cause). The systematic questioning techniques facilitate critical examination where each manufacturing activity and part is subjected to a systematic and progressive series of questions to identify the real causes of wastes and difficulties and facilitate improvements.

After gathering necessary details about parts, sub-assemblies, vendors, in-house/outhouse manufacturing of components, and integration requirements, research team could work out MCT of the representative product (discussed later). This could happen only after understanding the difficulties associated with different components, sub-assemblies, its integration in the final project (in ETO and other complex production environments, product is treated like project), and thus research team developed deeper understandings about the weaknesses in existing manufacturing management practices. It was decided to carry out a rigorous review of the parts/components based on the quantity, vendors, in-house or outhouse manufacturing, engineering nature and integration difficulties. This was necessary for the appropriate classification of components and applicable treatments, incorporating necessary changes and aligning vendor management strategies. Next subsections cover necessary details in context to chosen representative product and discuss in details about how rationalization is carried out. Figure 2 outlines major steps of the study.

4. Indian manufacturing scenario, existing vendor management practices and their shortcomings

Manufacturing has emerged as one of the high growth sectors in India. Prime minister of India launched “Make in India” program in 2014, to reposition India on the world map as a manufacturing and sourcing hub and to provide strategic global recognition to the Indian economy. As per the report of United Nations Industrial Development Organization, India ranks 6th among the world’s 10 largest manufacturing countries in 2015. India has recently launched a national manufacturing policy that aims to increase manufacturing contribution from a current 16 percent of gross domestic product to 25 percent by 2022 in order to achieve a growth rate of 12–14 percent per year (Sen *et al.*, 2015). With the help of “Make in India” drive, India has been developing, nourishing and nurturing necessary capabilities and expertise and is on the path of becoming the hub of hi-tech complex and project-oriented manufacturing. It is reflected in the increase in foreign direct investment and arrival of global giants like General Electric, Siemens, LG, Toshiba and even Boeing to name a few, which have either set up or are in process of setting up manufacturing plants in India, attracted by India's manufacturing capabilities and a strong domestic market of more than a billion consumers with increasing purchasing power.

Although in the previous subsections, authors have discussed in brief about vendor evaluation methods and gaps in the literature, authors still believe that some more light should be shed discussing about the weaknesses in conventional vendor evaluation approaches in Indian contexts. These weaknesses also influence manufacturing in ETO environments. Authors will discuss these weaknesses, considering three commonly used vendor appraisal methods in Indian contexts (Seth, Nemani, Pokharel and Al Sayed, 2018), which are categorical, weighted point and cost-ratio-based methods. Authors believe that more or less these weaknesses will also be applicable in other setups practicing these methods operating under ETO or other environments. Like other ETO companies, the case company was also following these methods. A very brief about these methods is as under.

Categorical method is a popular choice among Indian industries, but it is not a precise vendor evaluation technique. It relies heavily on the experience and ability of individual buyers. Here, buyer keeps a record of all vendors and their supplies. After establishing a list of factors for evaluation purposes, the buyer assigns a grade indicating performance in each area usually measured in terms of quality, delivery, credit period, etc. A marking system of +, − or neutral is normally used. In addition, evaluation lists are also given to all the departments concerned like accounts, quality Assurance, production and stores receipt. Periodic evaluation meetings are held where a buyer discusses the rating with the representatives of these departments. Later suppliers with high or low ratings may be notified and future business is allocated accordingly (Wu and Barnes, 2011).

Although this approach is non-quantitative, it does provide a means of systematic record keeping in terms of performance criteria. It is also inexpensive and requires a minimum of performance data. However, it relies heavily on the memory and subjective judgment of the individuals carrying out vendor rating. The possibilities are always there that the vendor rating-based segregation will become a routine feature with a minimum critical thought over other concerned/relevant issues.

Second commonly used vendor evaluation approach relies on weighted points. Here, depending upon the needs of company, five to ten numbers of evaluation factors are normally included. The relative weights of these evaluation factors can be expressed in numerical terms, so that a composite performance index can be worked out and supplier comparisons can be easily made. The major benefit of using this method is that subjective evaluation is minimized. Further, a number of evaluation factors can be included and they can be assigned relative weights corresponding to the needs of the firm. If the weighted point approach is used in conjunction with the categorical one, then vendors can be evaluated on a quantifiable basis without missing the intangible aspects of supply services.

Third commonly used method is "cost-ratio method" which relates to identifiable purchasing and receiving costs to the value of shipments received from respective vendors. The higher the ratio of costs to shipments, the lower the rating given to the vendor. The choice of costs to be allocated depends somewhat on the specific product involved. However, quality, delivery, services and price are the usual categories (Seth, Nemani, Pokharel and Al Sayed, 2018). The cost-ratio method of evaluation reduces the subjective element, common with other methods. Thus, it helps in establishing a norm of vendor supply services and evaluates a vendor above or below the norm in context to price of item supplied.

4.1 Shortcomings of these methods influencing manufacturing in ETO

These three methods are practiced to support buyer judgment and, in some cases, quantify what would otherwise be subjective analysis. Accordingly, these methods should normally be used as aids and not as a replacement for a buyer's judgment. In addition, many of the quantifiable variables are dependent initially on subjective decision. Important vendor-related variables like integrity, initiative, behavior and ethics are not easily quantifiable. Conventional vendor rationalization approaches do not take care of these issues. Besides, none of the methods consider the product as a whole and its components, design complexities, compatibilities of components and the manufacturing processes which are important issues under ETO environment.

As mentioned earlier, traditionally the vendors are selected based on their expertise in engineering, technical skill and financial stability and are constantly rated based on their past performance in terms of price, quality and delivery, without bothering for the difficulties and challenges that vendors face. This not only affects vendors but directly and indirectly contributes to increase in MCT for the final product and leads to following problems in Indian contexts:

- high level of co-ordination required (due to engineering-related challenges like tight tolerances, design difficulties and vendor not visualizing the whole product);
- large extent of materials movement and logistics problems;
- high level of follow-up-related requirements adding administrative overheads;
- high amount of other procedural work, and activities (like inspection, receiving and storage) involved along with statutory requirements like taxation;
- poor manufacturing, financial and technical capabilities expecting monetary and engineering support from buyer company;
- lot of reworks and adjustments at buyer's end to ensure fitment; and
- lack of interest of vendors in some case due to manufacturing difficulties, low volumes and profit margins, along with engineering design-related complexities and consequently causing delays due to such supplies.

This creates an urgent need to rationalize the vendors while working in ETO environment in a manner to resolve above-mentioned problems. The rationalization to be effective in the long term should focus on the win-win situation for both vendors and the clients.

In ETO types of business alliance, the buying organization wants the vendor to supply some unique or specialized product/service due to design complexities and other similar challenges. This often requires the vendor to invest in additional assets, specialized personnel and technology or to make some similar commitments. As in ETO supply volumes are always low, due to project-type (one-off) nature of business, vendor is demotivated. Over and above if the component/part to be supplied is uniquely very intricate or a high tolerance item, then vendor usually hesitates as it may lead to his losses, while he may not to say so explicitly, as it may affect his other business relations with the clients. The vendor finds it difficult to justify the expenses incurred in additional assets or the difficulties encountered. the vendor either expects more volume, or high margins on the components supplied by him. While a value added benefit is actually received by buying company, these benefits are not strategic or core to that organization's business success, if vendors interests are not taken care of. So, it is high time that instead of only looking at vendors (and their strengths and weaknesses only), the organizations should also look at themselves in order to improve vendor performance and to retain their interest in the alliance. Naturally, the buying organization cannot use one stick for all animals (one set of criteria for all types of supplies). In this scenario, prioritization alone will not be sufficient and some logical grouping will facilitate both vendors (in terms of support received from the buying company) and to the buying company in leveraging the capabilities of vendors. This will lead to a win-win situation for both.

5. Proposed vendor rationalization and actions based on Kraljic's matrix application

Conventionally vendors are assessed on the basis of their capabilities like manufacturing facilities, workmanship, financial stability and past performance in terms of price, quality and delivery. On the other hand, in terms of achieving real breakthroughs in reducing MCT, it is recommended to follow a strategy based on an application, which focuses not only on vendor selection, but also focuses on the continuous actions by the client company. It is proposed to group items/supplies requiring improvement actions toward their supplies considering the nature of items/supplies. It is decided that these improvement actions and corrective measures should be taken by the buyer company and will include actions like design reviews, design modifications, manufacturing process simplifications, tolerance adjustments and rationalization, design for assembly and manufacturability. Similarly, it is proposed to extend assistance and client expertise to vendors as long-term business partners. These actions will help to facilitate vendors, will be mutually beneficiary and ultimately will help in reducing the MCT and cost. Therefore, authors proposed a vendor rationalization based on the classification of components sub-contracted in following four categories, where the prime criteria are the design, manufacturability and fitment (integration) of the components for the final product influencing quality and cycle time reduction. The classification, their rationale and action strategy are mentioned in Table III.

Detailed application-based explanation about the actions for different groups of components as discussed in the next section is given below through a real life case study-based application.

6. Case study discussions details to address background for application

6.1 Profile of the company and nature of working

PQR company (because of confidentiality reasons, the name and details are not being disclosed) is situated in Mumbai, the industrial capital of India. The company is engaged in the manufacturing of high precision online weighing systems and other related industrial equipment for process industries like cement plants and chemical plants. It has technical collaboration with the firms of Germany and the USA and produces ten types of product lines, namely, industrial gravimetric weigh feeders, vibrating feeder, belt weigh, screen conveyor, apron weigh feeder, solid slow meter, bucket elevator, wooden slat conveyor, belt conveyor and bin-level measuring systems. Each product is custom-made and is treated as project and belongs to ETO manufacturing system. PQR's core competencies include excellent product design in collaboration with Germany, strong engineering department in India, skilled assembly shop and large vendor base, for its supply chain. It has manufacturing facilities which include different types of cranes, general-purpose machines like heavy duty drilling, welding, cutting, grinding, painting, etc. The total annual sales turnover of the company is over INR 97m (1$ = INR 65) and employs about 200 personnel. A good amount of manufacturing work is also sub-contractor fabricators in Mumbai.

S.No.	Classification	Action strategy
1	Troublesome components	Redesign the components using value engineering, review and rationalize the tolerances, based on the product essential requirements
2	Critical components	Extend help to vendors to improve/develop their manufacturing process capabilities
3	Non-critical components	Reduce number of vendors drastically based on conventional vendor evaluation methods
4	Standard components	Reduce number of vendors and negotiate further in terms of price

Table III. Classification of items and proposed actions from buyer company (case company PQR)

Customer orders for company PQR mostly comprise of individual unit, two and sometimes even three to four similar/dissimilar units of the products and are treated as an engineering project. For example, a typical weigh feeder bagging plant will consist of following sub-assemblies: storage hoppers with sensors, bin activators, twin screw feeders, de-dusting unit, weighing hopper, pulley assembly, roller conveyor belts, bag stitching machine and electrical control panel boxes.

Units and their variants may or may not involve standard parts, modules, casings, motors, gear boxes and common materials due to commonalities between variants. Every customer order is different, essentially requiring details about production routings to complete the final assembly and an individual BOMs. Typically, the company operates with low volume complex natured products, with possibilities of design changes as per requirements from customer side. The other challenges include project nature of working, stage-based tests due to engineering standards and additional fitments to cover testing/commissioning requirements of the products. The company was finding it difficult to compete in the market because of very high MCT, although the products quality was better in comparison to competitors in India.

6.2 Analysis: measurement of MCT using representative product data collection and associated problems

The company PQR for its wide range of products manufactures both standard and custom design options to accommodate the needs and requirements of customers. To cater this requirement, the company has an in-house team of designers and flexible production facilities comprising of general-purpose machines to make the engineering products as per customer orders. For the products manufactured by PQR, many variants and combinations are possible. Thus, for all practical purposes, the working of PQR can be treated as an industry operating on ETO products.

To withstand competition, factors like MCT and product quality are extremely important. It becomes even more important since the company is facing problems due to adjustments, reworks and corrections during assembly and testing contributing toward high cycle time and draining company's profit. Management of PQR is aware about these problems and is interested in all types of improvement-based strategies, propositions backed up with investigation approaches for reducing cycle times. Executives of company are convinced about wastes, rework and fitment-related challenges leading to high cycle time, and are sceptical about vendor rationalization approach-based application in this setup. Both company management and research team of authors are aware of the fact that it is difficult to capture the full range of variability in a single vendor rationalization exercise, because different products require different modules/components which have different sourcing and lead-time-related challenges from vendors side. Similarly, the production process routings will also be different with or without interactions. This makes it extremely difficult and challenging to apply the vendor rationalization in a logical manner.

In this situation of ETO setup, a workable and practical solution can be to identify a representative product and apply vendor rationalization-based analysis to it in order to understand difficulties, problem areas, bottlenecks, and various rework and adjustments-related wastes to decide their impact on manufacturing and delivery cycle times. To identify a representative product (one popular variant), authors reviewed previous years records, discussed with executives and based on the available data, for the present case, microprocessor-based gravimetric industrial weigh feeder for cement plants, with a capacity of 60 tons per hour capacity is chosen as a representative product for vendor rationalization application. Table IV gives the general details like value, number and nature of components, standardization requirements and number of vendors based on overall BOM for this category of products. The high-value standard components include electric motors, gear boxes, conveyor rollers, etc.; medium value include bearings, small pulleys, pulley belts and some flanges; and low value standard components included various type of hardware items like nut, bolts, washers, small pulley belts, etc.

The cycle time analysis is carried out for this product category of weigh feeders only (which represents about 60 percent of total business value, considering its different variants). For the estimation of MCT, three representative orders were chosen as sample to analyze the time buckets incorporating major sub-assemblies like frame, hopper, discharge chute and belt-pulley arrangements and program evaluation and review technique(PERT) charts were drawn for them with starting and finishing dates for various sub-assemblies covering operations. These dates were collected from engineering release, goods receipt note documents, excise documents, shop floor log books and discussions with relevant persons.

The analysis highlights following specifics: average MCT was 80 days, considering finish final assembly date–engineering release date. It was noted that biggest contributor to MCT was hopper assembly, whose MCT itself was = 43 days. The PERT diagram for this hopper assembly is shown in Figure 3 as a sample, based on the three representative orders mentioned above. Similar PERT charts were made for each of sub-assemblies listed in previous Section 6.1, and also for the overall assembly of sub-assemblies, which provided the total MCT of 80 days for the total product, including testing and packaging. Procurement long lead time items for items like motors, gear boxes were planned much in advance. Other sub-assemblies contributing to high lead time were pulley sub-assembly, main frame sub-assembly and discharge sub-assembly.

The MCT of 80 days was very high by any standards, especially when all the manufacturing and vendor activities were local (in Mumbai only). The main causes of the delays were identified as follows:

- A large amount of rework and rectification both in-plant and at vendors' places was noticed. Surprisingly, most of the time, the total amount of rework and rectification was found to be far more than the real value addition time.
- For about 1,326 purchased components, there were too many vendors, like about 203 vendors in Weigh Feeder, to deal with, which created tremendous problem of communication and co-ordinations with them. There were some designs complexities with sub-assemblies (e.g. hopper design), which were difficult to manufacture by vendors and problematic to assemble at company end. There was a need to rationalize the problematic designs (from manufacturability point of view) and also rationalize the vendor base, in order to reduce the delay.
- The production planning method was weak from two points of views. One, it involved lots of manual compilation activities at users end (e.g. at vendor

Representative gravimetric weigh feeder							
Value of components	Total number of components	Approx. % of total cost contribution	Standard items bought from market	Number of vendors	Non-standard designed components made in-house	Non-standard designed components outsourced	Number of vendors
High value	87	78	52	27	12	23	10
Medium value	212	16	67	44	51	94	23
Low value	1,167	6	933	56	77	157	43
Total	1,466	100	1,052		140	274	
	Number of vendors	203		127	Not applicable		76

Table IV. Value, number of components, standardization requirements and vendor-related details for representative product

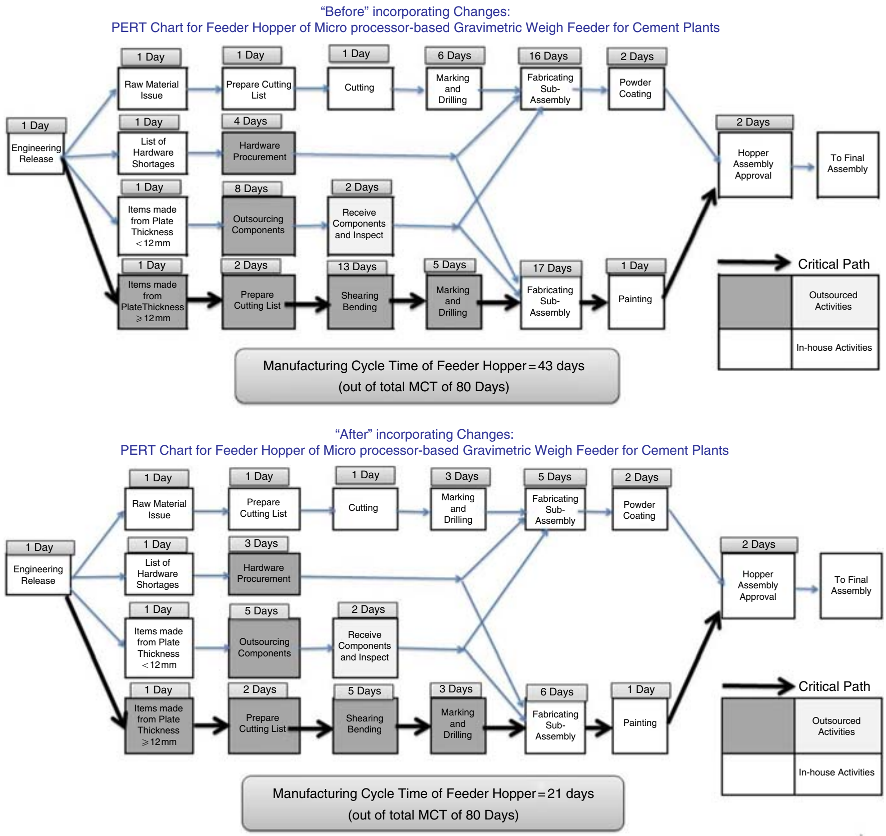

Figure 3.
PERT chart for MCT of feeder hopper as sample sub-assembly before and after rationalization

development department, at production and at production planning level) which were causing delays. Similarly, another weakness was that the system did not ensure the synchronization of availability of various components/sub-assemblies from various sources (like production, vendors, purchase, etc.). In this situation, delay of even low value items will delay the assembly and result in occupying a large horizontal expensive space in the plant. Mumbai space being one of the most expensive in the world added unnecessary cost to the product and also reduced the assembly capacity of the case company.

There was an urgent need to review the sub-contracting policies from logistics point of view as well.

6.3 Application of Kraljic's matrix and allied recommendations

Keeping in mind the high MCT, vendor rationalization based on Kraljic's matrix was applied along with manufacturing processes and design-related changes, for better manufacturability for the outsourced 274 components. Accordingly, with this objective, the outsourced components and sub-assemblies were classified into four categories on the basis of design, manufacturability and fitment/compatibility. The vendors were also grouped/categorized accordingly. Suitable corrective actions and measures were suggested for the vendors who would handle each class of items along with changes in policies required for improvement. Table V is the summary of components, including 274 components classified into four Kraljic's matrix-based categories. For the sake of completeness, the number of in-house manufactured and standard components bought from the suppliers including some original equipment manufacturers is also listed. The detailed description of these classifications of components and some sample components explanations are provided in the paragraphs below (Table V), which discusses Kraljic's matrix-based classification.

6.3.1 Troublesome/bottleneck components. Out of 274 outsourced items, about 32 are the supply items, which are either of very complex designs, or require very complex manufacturing processes due to high tolerance requirements and intricate geometry of components. Vendors although do supply these components also, but are very reluctant, and show their technical hitches/difficulties in supplying these items. This happens because the design or manufacturing complexity clashing with vendors' business interests of making some minimum amount of profits. The vendors feel that they are not getting profit margins for the efforts and resources that they are investing in these items. Some of the 32 components of weigh feeder that fall in this category are gussets of hopper assembly (complex manufacturing and high rework); knife-edge for belt ware (complex design and manufacturing) and fulcrum knife-edge (complex design and manufacturing-based challenges due to very tight tolerances).

For example, knife-edge for belt ware, which was an import substitute item, was very critical item for the product. But its complex design caused its making a difficult task and made its profit margin negative, often resulting in delayed supply. The price for this component was on the basis of its weight, based on the prevalent procurement practices, which could not be changed. On closer scrutiny of design, it was observed that the basic function of knife-edge was to act as a fulcrum. So with small modifications in design leading to easier fabrication, the item could be made profitable to vendor, without changing the price to PQR. Thus, a bottleneck could be reclassified as a non-critical or standard item. Many times such items cause bottlenecks or even become bottleneck, at assembly area resulting lots of delays for MCT. For such category of items, it is advised to review/change the design of the items and simplify them for their intended purpose through value engineering exercises applied to products and processes (Kendt and Nichols, 1992). For such items after careful design-based reviews/corrections/value engineering-based changes, it is not at all necessary to select or develop a new vendor with higher capabilities. This modification not only simplifies manufacturing of the components, but also increases the comforts of both vendor and assembly people working on shop floor. This leads to a win-win relationship between the two stakeholders.

6.3.2 Critical components. Unlike troublesome 32 items, these are about 38 items for which there is no hitch from vendors to supply. However, the supply of these items requires good engineering skills and manufacturing knowledge to produce at vendor end. These items are very important and crucial to the final products for their performances. The items

S.No.	Classification	Number of components
1	Number of components outsourced, classified as troublesome/bottleneck	32
2	Number of components outsourced, classified as critical	38
3	Number of components outsourced, classified as non-critical	204
4	Number of components outsourced, classified as standard	1,052
5	Number of components made in-house	140
6	Total number of components	1,466

Table V. Kraljic's matrix for the classification of components from the representative product of PQR that may be put under this category are pulley assembly and electrical panel box.

For example, pulley assembly of weigh feeder was a critical part of weigh feeder because of the driving mechanism was attached to it. The assembly consisted of a shaft, bosses and flanges on either side and outer cylinder. The pulley was machined by vendor-I, while vendor-II machined the boss, flange and other cylinder. The assembly of pulley and shaft was carried out at PQR, where difficulties were faced in assembly due to desired dimensional inaccuracies, and problems due to multiple vendors' involvement. For such items, it was recommended to extend the company's support, expertise and engineering skills through company engineers (from quality control, engineering, production, etc.) to help in developing the vendors. This support and guidance to the vendors would help them to take extra care of requirements of critical dimensions and processes. This would also avoid any delay at company's end due to rework, mismatch, corrections and sometimes costly rejections.

6.3.3 Non-critical components. Remaining 182 outsourced items are having simple designs and manufacturing processes, which can be performed by any vendor with an average quality of facilities and performance ratings. Some of the items which belonged to this category in PQR are: skirt board, load cell covers, junction box drilling and small cabinet for housing.

Since these items can be made by any average vendor and do not require any special manufacturing capabilities, it is recommended to reduce the present large number of vendors drastically to a small number (say by 90–95 percent). This will reduce the need for high co-ordination, corporation and communication drastically, and would also increase the business size of each of the retained vendors. This would also make them happier as well and will give leverage to the company for better prices negotiation due to bulk business. The conventional method of vendor appraisal based on analyzing past performance in terms of price, quality, delivery, financial soundness could be used for this purpose.

6.3.4 Standard components. About 1,052 items are standard purchased items, which are required in bulk and design is not at all a cause of concern. Due to simplicity of design and manufacturing, a large base of vendors is available for supplying. For example, mechanical hardware like washers, bolts, studs, nuts and screws are items required in large volumes. Their specifications are simple enough to have many options of suppliers. Here also, the existing suppliers can be drastically reduced and volumes of business can be consolidated to limited preferred vendors, to be used as leverage for negotiation for competitive prices and required delivery schedules. Therefore for such items, a very small set of vendors, who could provide items at very low prices for bulk total volumes, should be retained. Every attempt should be made that these vendors should be physically located as close as possible to the client, so that just in time deliveries can be ensured based on the blanket contract price for the supply of items for the year. However, for high and medium value standard bought out items like electric motors and dial gauges, etc., the number cannot be reduced drastically. Here, finally 127 vendors of standard items could be reduced to just 41.

Table VI shows the rationalized number of vendors after six months of efforts with respect to representative product (gravimetric weigh feeder).

Table VI. Vendor rationalization demonstrated for representative product

Nature of items/components	Standard items bought from market	For non-standard components outsourced	Total
Number of vendors	127	76	203
Reduced number of vendors	41	20	61
% reduction of vendors after rationalization	67.7	73.6	69.9

7. Benefits realized after application

Following main benefits of this vendor rationalization application were noticed.

As discussed earlier, after the proper categorization of supply items, based on Kraljic's matrix application, weaknesses and difficulties causing delays were exposed and the needs for improvement actions, design reviews and corrective measures were imminent. Similarly, shortcomings of existing vendor appraisal approaches and manufacturing practices of correction, adjustments, rectifications, adjustments and rework of parts on the shop floor were also evident. These manufacturing practices which were causing lot of wastes, delays and increase in indirect costs were directly dependent on poor vendor management.

To address these shortcomings and weaknesses, serious design reviews, rationalization of tight tolerances for quality control and functional requirements of each component/part/module were carried out for 70 troublesome/bottleneck and critical components. This was necessary to unearth the hidden and unneeded complexities associated with parts and components, causing lot of difficulties and delays both at vendor and company ends. By systematic design reviews and using value engineering-based small changes on a fast track, bottleneck items were converted into either critical or non-critical items. The vendor management strategy was revised keeping in mind the nature of critical components of weigh feeder and the need to extend financial and engineering support to selected vendors. These items were critical not only in terms of cycle time but also critical toward the overall quality of the final ETO product.

Similarly, vendor base for standard items and non-critical components was drastically reduced and attempts were made to smoothen the procurement procedures. As a result of all these measures, about 60 percent reduction in MCT was achieved over a period of six months. As a sample, Figure 3 shows the new cycle time for the feeder hopper assembly, which was reduced from 43 to 21 days. It may be noted here that the precedence relationships in the PERT diagram of the feeder hopper are not changed, but the sub-assemblies lead times and procurement times have only reduced to much smaller due to faster supply of materials and negligible shortages of items. The critical path also changed after modifications. The earlier cycle time was 80 days and the new cycle time after vendor rationalization implementation was about 32 days. Similarly, other direct and indirect cost benefits were realized in the company due to a significant reduction in co-ordination workload. Now the company could use higher volumes and long-term relationships as a tool to achieve reduction in cost of outsourcing. By consolidating business to vendors and reducing total number of vendors significantly, indirect costs like order chasing, expediting costs, keeping track of schedules follow-up on payment of dues, and procedural work related to each work order were reduced drastically. This also reduced workload on purchase, stores and accounts departments.

Other significant benefit was reported due to better buyer's powers. After vendor rationalization, by reducing number of vendors by about 70 percent and consolidating business given to each vendor, the case company was in a better position to negotiate supply conditions with respect to payment terms with the vendors. About 8–9 percent cost saving was also estimated due to this consolidation and negotiations with vendors.

Further, since the assembly of the Weigh Feeder now takes only 32 days, the assembly capacity of the plant more than doubled compared to its current capacity, without any capital investment. This is a very major benefit in the growing demand market. Finally, the overhead allocation of the cost of expensive space in Mumbai also reduced, adding to the profit of the company.

By applying this vendor rationalization-based approach, it was possible to reduce the total number of vendor base by more than 70 percent, and about 60 percent reduction in MCT, besides reducing the project cost, for this product line of PQR, successfully.

The application of Kraljic's matrix was just a starting point with reference to one of the key products for the company (representative product in this case). The executives and top management were enthusiastic in further extending this vendor rationalization strategy for other products and then attempting for final consolidation of vendor base keeping in mind the business needs of the company.

8. Findings, conclusions and research message of the study

The commonly held view, vendor rationalization means reducing the suppliers, is not always optimal and should be modified considering the strategic needs of the company, keeping in mind the complexities associated with manufacturing environment. It is much more than how a company manages engagement with vendors. Vendor rationalization will make better sense, if one considers different type of values it provides to different stakeholders.

8.1 Value to customers

As noticed in this case study, cycle time for delivery became less than half, and the quality of the components also improved. It is expected that the customer will be more satisfied, in terms of faster responsiveness, as well as can afford to invest extra one to two days for more rigorous testing for quality of performance, without the risk of delay for delivery. Therefore, the customer is more likely to be satisfied than before.

One more important thing is for customers the complete assembly of important components. Shortage of even a few small very low value components also is not acceptable. Therefore, the reasons for delay for even such items are important, and if some of these are troublesome/bottleneck or critical components, these must be corrected in terms of design changes or tolerances rationalization.

8.2 Value to producers

For the producers, the cost of the each customized product comes down due to two reasons. One is lesser MCT, giving more output from the same facilities, hence greater profits and revenue. Besides, due to this, the overhead cost of the huge space occupied for the assembly and testing in costly cities like Mumbai will reduce this overhead allocated to the product. Finally, higher quality of purchases will also lead to better price negotiations because of economy of scale, and will improve the profits by cost reduction.

8.3 Value to investors/shareholders

Shareholders can expect greater dividends due to profit increase by 7–10 percent. Greater cash reserves will also come due to greater revenue and profits, due to enhanced capacity in growing demand scenario.

8.4 Value to vendors

Good vendors are really greatly beneficial in terms of assured greater business over the years, as well as greater profits due to the rationalization of designs and tolerances in troubled components. Their commitment will grow, since the client company takes care of their problems. Of course, the bad vendors will be the losers.

8.5 Value to employees

The employees in procurement and assembly will be much happier due to far lesser number of vendors to be handled, that too better ones, and timely supply of the components. The stress levels of the employees will come down. They are also likely to get better compensations as the profit margins of the company will increase.

The changes in value propositions to the PQR organization after vendors rationalization using Kraljic's matrix are summarized in Table VII, based on above discussions.

	Summary of the value of vendor rationalization	
Stakeholders	Before	After
Customers	Dissatisfied generally due to delays and late deliveries	Satisfied due to faster delivery and low variance between promised and actual deliveries More time provided for in-company testing and inspection, without getting the supply delayed
Producers	Delayed product/project deliveries Heavy amount of follow-up required on day-to-day basis Not able to meet growing market demand due to space limitations in assembly	Faster product/project deliveries Cost savings due to vendor consolidation and reduced system assembly time to almost half Increased capacity of system assembly, making it possible to increased capacity, without much capital investments
Vendors	Dissatisfied vendors, due to low or no profits in many parts supply Delays in payments	Far greater annual assured business Greater revenue and profits Less hassles due to manufacturability problems
Employees	Very stressed way of working due to heavy follow-ups and co-ordination with large number of vendors and rework/adjustment problems on shop floor Working overtime for most of the days in the month	Better co-ordination among almost reduced to 30% of the better vendors Getting time for further improvements without working overtime
Shareholders/Investors	Not so good dividends	Additional (expected) bonus dividends due to greater revenue and profits

Table VII. Changes in value propositions to different stakeholders before and after rationalization

Thus, vendor rationalization with Kraljic's matrix, unlike vendor selection, rating and prioritization will provide a far greater value to all the stakeholders.

8.6 Research message from the study

Vendor rationalization is all about making periodic changes and strategic alignments in terms of supplies and vendors based on knowing: who you are buying from, what type of items and how much you buy, what types of risks you tolerate, what types of reviews you carry out in terms of design/making difficulties considering usage/integration requirements, what type of support you offer and ultimately how much it costs you in your company directly and indirectly to do so.

These logical questions should be answered considering the requirements of manufacturing environments and their complexities, covering procurement costs, co-ordination hassles, integration/fitment of components to ETO product/project, impact of supplies on the final product in terms of quality, rework, wastes, cycle time and risks-based considerations. Therefore, vendor rationalization is not about vendor base reduction but all about building, maintaining and developing vendor base that gives "best overall business fit" to the company.

It is observed that researchers remain busy with complex mathematical MCDM and operations research-based modeling and overemphasize vendor evaluation/prioritization aspects. Unknowingly or knowingly, it is believed that MCDM-based prioritization of vendors will take care of problems related with supplies and integration-related hurdles and will help in smoothening the supplies, costs and cycle time reduction. This never happens in real life. Similarly, when they follow purchasing models, they get entangled into costing and accounting details. Unfortunately, with these two conventional ways of dealing supplies and vendors, they often miss the strategic integration requirements, based on the needs of manufacturing environment. In context to manufacturing environments, the nature and type of item/component/module should also be taken into account along with these two conventional ways of dealing supplies, vendors, vendor management and procurement.

Cross-functional integration of components is an essential requirement in complex manufacturing environments like project/ETO and a logical grouping based on Kraljic's matrix can facilitate to achieve both cycle time reduction and operational excellence.

The hoary old myth that one can get the best price by maintaining multiple vendors and playing them off against one another for extracting under-cutting responses to lower costs may not be the true in real sense and may not be the best choice today. Unfortunately, the case company was doing the same thing. Circumstances have changed. Today's vendor management is configured around co-operative business partners arm-in-arm relationships, not by adversities in transactions.

The executives should understand that a low price for components may hide a high rate of rejection and rework which not only delays MCT but ultimately adds to company's cost, resulting in much lower profitability. On under-cutting, vendor may eventually go out of business, forcing the buyer to deal with a prohibitively expensive vendor, next inviting lot of supply risks and invisible impact on business. It is the time that instead of rating the vendors only on traditional parameters, and using approaches like MCDM-based prioritizations, the organization should look at itself and rationalize the design and tolerance requirements of the components using concepts like value engineering to product and process. Even for troublesome components, there is no need to select and to develop new vendors with high capability. The rationale is that instead of evaluating, and prioritizing vendors using complex mathematical exercises, a critical look at the components is a must and it should be the focus of any vendor rationalization strategy to reduce MCT under ETO or project environment.

9. Limitations of the study and future directions

This research study work has some limitations as it discusses the vendor rationalization application in a specific ETO company case. An ETO firm in one particular setup may differ from another firm in terms of variety of products, vendor dependence, scale and nature of operations, and other constraints. Another limitation may be due to the selection of representative variant with a focus on making aspects and some compromises in terms of collection of micro-details while working out the cycle time. Other ETO-related challenges like design iterations, BOMs, routing, machine dedication rates and risks were not considered, only vendor aspects were stressed (Gosling *et al.*, 2015). Authors did not take into account information technology, e-commerce and internet software-based co-ordination support (Mohanty *et al.*, 2007) related considerations. It also leaves scope for transportation and inventory-related considerations (Seth and Pandey, 2009) as one deals with high cost items.

Some scholars may not accept this application-based research as case study. For this requirement, authors would like to clarify that in literature, many single application-based studies are available, which are presented as case study. Authors would like to cite some of them (van Aken, 2004; Seth *et al.*, 2008; Pachpor *et al.*, 2017) both from and outside *Journal of Manufacturing Technology Management*.

To keep the application message simple and generic, no modeling- or simulation-based verification was attempted for scenario generation requirements. As the vendor rationalization and strategic alignment-based changes were actually implemented in the case company PQR, this study can be extended in different manners.

Authors would like to appeal to both researchers and practitioners to consider vendor rationalization requirements based on the integration needs of the product/project, along with criteria selection and vendor evaluation exercises. Vendor rationalization should be urgently attempted in complex production environments like construction, ETO and high-mix low-volume manufacturing setups for operational excellence and cycle time reduction. This exercise should then be extended to other manufacturing environments and should be tried in different sectors and country-specific setups. Authors also appeal to researchers and practitioners to develop new classification schemes based on vendor rationalization for components and propose extensions or modifications in Kraljic's matrix. The age old assumption, "vendor prioritization" means everything with respect to supplies, does not hold true in many situations. Similarly, in vendor management exercises, the engineering nature and type of items should be essentially included along with purchasing, manufacturing, inventory, shop floor integration/co-ordination, and supply chain management considerations.

An attempt can also be made to implement Kraljic's matrix with some suitable hybrid framework covering the requirements of both manufacturing and supply chain management like Lean Six Sigma, as proposed by review and application studies like Lande *et al.* (2016) and Yadav *et al.* (2017, 2018a, b). In this manner, vendor rationalization through Kraljic's matrix and hybrid concepts like Lean Six Sigma can support each other.

Similarly, green manufacturing, sustainability and cleaner production considerations (Dabhilkar *et al.*, 2016; Rehman *et al.*, 2016; Seth *et al.*, 2016; Seth, Rehman and Shrivastava, 2018) with various risks, design challenges and vendor alignment reviews can also be brought under the umbrella of vendor rationalization applications. More studies with these challenges will add value to this scheme of vendor rationalization and will help in extending vendor management body of knowledge. Authors believe that these endeavors will open up new research fronts for both ETO and non ETO environments and will also motivate researchers and practitioners to leverage vendor rationalization-based improvements.

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