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Engineering Design and Innovation in a Global Context

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1 Introduction

In the drive for high value engineering, traditional engineering design, product development and innovation processes are evolving. A large number of companies have long since outsourced or offshored their

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production facilities. More recently, trends amongst a number of companies have been observed to outsource and offshore the earlier and more valuable phases in the engineering value chain, including development. This chapter examines the global product development process, which for many companies is a very much learning-by-doing approach, and examines how to support decisions to globalise parts of the development process and monitor the impact of these decisions. Understanding the impact of these decisions can lead to a stronger understanding of how to create high value engineering, whereas as global product development is examined here very much from the perspective of a firm as the key stakeholder whilst outsourcing or offshoring parts of their development, the role of multiple stakeholders is recognised in open innovation processes taking place between stakeholders, in particular within high value engineering networks. These are discussed here.

2 Open Innovation

2.1 Introduction to Open Innovation

The successful creation and capture of new value with global high value engineering networks relies upon the effective collaboration between multiple stakeholders. The complex and dynamic nature of these networks, coupled with the systemic characteristics of many emerging technologies, means that no single company is likely to be able to manage the process of successful innovation on its own. One model that has emerged to describe and support the collaborative approaches required to innovate successfully within global high value engineering networks is *open innovation*.

2.2 How Open Innovation Approaches Can Support Value Creation and Capture for High Value Engineering

As has been widely documented (Chesbrough 2003b; Chesbrough et al. 2006; Huizingh 2011) a number of factors aligned to change the way in which companies innovate over the past two decades. By observing and reflecting on these factors and the lessons provided by the examples of success and failure in leading corporations, a coherent model for describing and operationalising this emergent approach to innovation—*open innovation*—was articulated by Chesbrough (2003b). As part of this model, Chesbrough indicated that firms should on one side access and absorb external knowledge, combine it with internal knowledge to produce innovation (inbound process). At the same time, firms should consider a variety of potential outlets, also beyond the traditional route to market, for the exploitation of the innovation (outbound process).

The management of many leading firms recognised that open innovation presented a potential solution to address the diminishing competitiveness of their current innovation infrastructure and used open innovation as the model around which they could transform their approach to innovation.

The shift towards openness in innovation had been gradual, and examples can be traced back long before the publication of Chesbrough's initial articulation of the open innovation model in 2003 (Di Minin et al. 2010). However, the widespread diffusion of the core open innovation concept gave firms an explicit model for planning, communicating and implementing open approaches to innovation (Mortara and Minshall 2014). Historically, firms who developed open approaches to innovation prior to the publication of the book were led by an 'effectual' decision process (Sarasvathy 2001), i.e. as a result of particular contingencies such as the need to respond to major crises, many forms of openness were experimented with to help the companies survive. The articulation of the open innovation model in 2003 provided some firms with a language to describe activities already ongoing. Other firms were thus able to direct efforts to establishing and deploying open innovation programmes based on Chesbrough's model and visible examples of other firms. Approaches to the implementation of open innovation can therefore be seen as having two phases—one characterised by effectual implementation logic and the other by causal implementation logic—separated by a 'discontinuity' in 2003 (Mortara and Minshall 2014).

2.3 Challenges that Need to be Overcome When Using Open Approaches

There are many potential enablers and obstacles for the successful implementation of open innovation (Mortara and Minshall 2014). Here, in the context of high value engineering, we particularly consider three:

- The implementation of the necessary elements which enable firms to implement the new open innovation routines (e.g. culture change incentives).
- Considerations regarding how distance (geographical or mental) between organisations might impact on the flow of knowledge between organisations.
- The role change of particular agents, such as universities, in the innovation ecosystem.

Culture is most often seen as a barrier in the adoption of open innovation in large companies but has also been identified as an enabling factor (Mortara and Minshall 2011b). Lichtenthaler and Ernst (2006) defined six different attitudes which could distort, act as barriers or overplay the importance of open innovation, of which the 'Not-Invented-Here' (NIH) syndrome (Katz and Allen 1982) is the most frequently cited one. Authors have highlighted a range of issues to overcome the cultural barriers: several authors have highlighted the role of demonstrator projects as important enablers for the acceptance of open innovation (Chiaroni et al. 2011; Westergren and Holmström 2012). Westergen and Holmström (2012) showed that the building of trust with external partners supported the implementation of initial open innovation projects, and thus provided a demonstrator for further collaborative activities. Mortara et al. (2010a) noted the role of 'champions' to support different groups within the firm with different open innovation approaches, providing specific types of motivators in accordance with underlying subcultures. Particular emphasis was placed on the delivery of skills (Mortara et al. 2009) and the creation of boundary spanning objects (Tushman and Scanlan 1981; Fleming and Waguespack 2007). Control mechanisms such as incentives were found to have a positive impact on external (outbound) (Persson 2006) and internal (Minbaeva 2005) knowledge transfer and on the search performance (Salge et al. 2012). Whilst a firm's culture is clearly important, national (Savitskaya et al. 2010) (Chesbrough and Crowther 2006) and regional (Tödtling et al. 2011) cultures may also impact on open innovation implementation.

Within the context of high value engineering networks, the specific location of open innovation-related resources, activities and organisations needs particular consideration. Location in the context of open innovation can be considered in terms of (a) absolute geographic location; (b) proximity to a specific resource; and (c) an organisation's position in a network (Minshall et al. 2014). An organisation's *geographic location* determines the system of innovation within which it operates, and that may qualify it to take part in certain activities (e.g. eligibility to apply for certain regional funding and innovation support programmes) (Edquist 2005) and access other infrastructure elements (e.g. engagement with local universities and colleges) (Huggins 2008; Karlsson 2008). *Proximity* can be viewed in two ways: as relative geographic location or spatial distance, and as relative organisational/cultural compatibility or cognitive distance (Asheim and Gertler 2005; Moodysson et al. 2006; Huggins 2008). Cognitive distance is considered to be more important than spatial distance for knowledge transfer, assimilation and application (Asheim and Gertler 2005). Finally, a firm's *position in a network* can both enable and constrain opportunities for access to external knowledge and new markets and influences the likelihood of knowledge received being novel (Powell and Grodal 2005). Moreover, it determines the relational/social assets and capabilities it can create or gain access to (McEvily and Zaheer 1999). How a high value engineering firm engages with resources and activities to support its open innovation at a particular location can be considered in terms of whether these resources and activities can be accessed remotely, need to be attracted to be closer to the firm, or whether the firm needs to relocate some aspect of its operations closer to the resources or activities (Mortara and Minshall 2014).

One important set of location-related resources for supporting open innovation in the context of high value engineering firms relates to universities. The past 20 years have seen universities become increasingly important components of science and innovation policies in many nations, with growing pressures from government and industry for them to become increasingly strategic actors in processes of innovation and economic development (Deiaco et al. 2012). Indeed, universities have been evolving to become more deeply and strongly linked into the innovation system, and more directly engaged in processes of innovation (Perkmann and Walsh 2007; Youtie and Shapira 2008).

Universities have the potential to contribute to high value engineering firms' innovation processes directly and indirectly (Cohen et al. 2002; Laursen and Salter 2004). Companies can approach universities through different, often institutionalised channels for collaboration. Possible collaboration mechanisms include accessing intellectual property offered by university technology transfer offices, building long-term research collaborations with university departments, sponsoring student activities, or through involvement of spin-off companies based on university research (Chesbrough 2003a; Youtie and Shapira 2008; Breznitz and Feldman 2012). However, engaging with universities globally as part of a coherent high value engineering network strategy is a capability that not all firms may possess, and thus may require dedicated efforts to develop (Minshall et al. 2015).

2.4 Summary of Processes/Tools That Can be Used to Support Open Innovation with Different Partners Relevant to Value Creation and Capture in a HVE Context

Open innovation provides high value engineering firms with the ability to create and capture new value via networks. However, as shown above, successful use of open approaches to innovation rests upon the firm's ability to overcome certain barriers, and these barriers may be linked to a wide range of factors including:

- The role of culture and, in particular, NIH syndrome (Katz and Allen 1982) in the implementation of open innovation (Mortara and Minshall 2011a).
- Understanding the role of internal R&D capacity (Cassiman and Veugelers 2006; Berchicci 2013) and its links to absorptive capacity (Bogers and Lhuillery 2011).
- Adopting specific management practices to support the implementation of open innovation (Salge et al. 2012).
- Targeting the use of IT systems, as seen in the experience of P&G (Dodgson et al. 2006) and Italcementi (Chiaroni et al. 2011). IT infrastructure is seen as a moderator for open innovation as it helps enable communication across boundaries and networks (Boscherini et al. 2010) and as an element of control (Kuschel et al. 2011).
- Applying specific management tools (Griffiths et al. 1998), taxonomies (Di Minin et al. 2010) or 'watch lists' (Tao and Magnotta 2006; Mortara et al. 2010b) can also be used to find the balance between what to do openly or internally.
- Adopting appropriate location-related activities for different open innovation strategies, i.e. moving operations to specific locations versus attracting organisations to move closer (Minshall and Mortara 2016).
- Understanding the impact of the adoption of 'virtual' platforms for carrying out specific innovation activities across networks (Bughin et al. 2008).
- Appreciating that a change of strategy (such as a shift to a more open approach to innovation across a high value engineering network) is often linked to leadership, the political climate and the internal dynamics of power need to be viewed as moderators in the adoption of open innovation (Pye and Pettigrew 2006).

3 Global Product Development

The establishment of global production sites in low-cost regions is a key force in inducing a more recent trend in Western manufacturing companies—the global distribution of product development (PD) activities. There are many terms in the literature to describe this trend such as the internationalisation of PD, distributed PD or a form of virtual, collaborative PD. In this chapter, we refer to the trend as global product development (GPD), which involves the globalisation of tasks and activities throughout the PD process, from the early concept development stage and detail design through to the final testing of prototypes before production.

The transformation from collocated, cross-functional PD to GPD represents a major transformation in industry today, and companies face the difficult decision of which PD tasks to keep in-house, and which tasks to distribute to independent foreign providers. The following sections outline some of the key impacts associated with GPD, the current practice for decision-making and conclude with recommendations towards a structured decision-making process in GPD.

3.1 The Impacts on the Product Development Process

In engineering design literature there are two terms often used to describe the different sourcing modes in GPD, namely: *offshoring*, the company expands PD to foreign countries whilst maintaining full ownership and control of the subsidiary, and *outsourcing*, the company hands over specific tasks and activities during PD to independent foreign providers. Different sourcing modes have been found to apply at different stages in the PD process. For example, during several case studies Hansen and Ahmed-Kristensen (2011) observed that low value adding activities at the back end of the PD process, such as testing of prototypes before production, were typically outsourced and high value adding activities, such as conceptual development, were typically offshored. The decision to outsource or offshore parts of PD is often driven by the opportunity to reduce development costs. In a survey conducted by the Aberdeen Group (2005), 78% of the 125 manufacturing companies pursued GPD as a strategic decision to reduce PD costs by utilising low-cost, skilled engineers distributed globally. Several studies reaffirm cost reductions as a key motivation for GPD whilst also highlighting less tangible drivers, such as increased access to new competencies and expertise, increased customer base and a reduction in proximity to global markets (Eppinger and Chitkara 2009). Despite the potential benefits associated with GPD the migration from conventional PD, which typically involves the coordination of collocated, cross-functional engineering teams to a form of GPD, which involves the coordination of engineering teams that are globally dispersed and culturally diverse, does not come without challenges. Whilst physical proximity can reinforce social similarity, shared values and expectations, the distance between engineering team members can lead to significant declines in communication and interaction. However, recent studies indicate how companies may have underestimated the challenges with GPD (Eppinger and Chitkara 2009). For example, during their study on collaborative PD in UK manufacturing firms, Littler et al. (1995) highlight how the time required to coordinate GPD increased in comparison with local, cross-functional PD, and the maintenance of the collaborations became the prime objective rather than the development of the product itself. During several case studies, Hansen and Ahmed-Kristensen (2011) found that in an environment where the distance between teams was increased and frequent, spontaneous interactions were reduced; complex development tasks became more difficult to manage and resulted in cultural misunderstandings, design rework and project time delays. Furthermore, the companies were found to switch between outsourcing and offshoring modes, adopting a learning-by-doing approach to GPD, with decisions being made on an ad hoc basis as the collaborations progressed. Given that GPD is a more recent trend in relation to the globalisation of production, it is likely that decision-makers have limited experience prior to embarking on GPD. However, the studies highlight how implementing solutions to challenges on an ad hoc basis can be costly.

The studies exemplify some of the positive and negative impacts of GPD. The learning-by-doing approach indicates the uncertainty companies face when embarking on GPD and highlights the need for a better understanding towards decision-making in GPD. More specifically, the need to support management to make more *informed* decisions during GPD, rather than those that are ad hoc, has been highlighted in the literature (Eppinger and Chitkara 2009; Westphal and Sohal 2012).

3.2 The Role of Information in Strategic Decision-Making

There are four main approaches discussed in the literature for decision-making, namely rationality, bounded rationality, politics and power and the garbage can paradigm (Eisenhardt and Zbaracki 1992). Since there is a need for more informed decision-making and the rational decision approach is founded in information-based decisions, this section focuses on the rational decision-making in the context of outsourcing and offshoring PD. Rational decision-making is characterised by situations whereby actors enter decision situations with known objectives that determine the value of possible consequences of an action (Eisenhardt and Zbaracki 1992). In other words, the approach assumes that there are clearly defined goals for the decision, and that it is possible to systematically choose between different options based on reasons and facts. During Citroen's (2011) investigations of the role of information during strategic decision-making, he concludes that decision-making processes rely heavily on both internal information, such as documentation from the firms' intranet, and external information, such as market information. Decision processes are likely to be influenced by increased availability of information throughout the process. In another study investigating decision-making in design and engineering outsourcing, Shishank and Dekkers (2013) claim that existing decision-making frameworks do not take into account the characteristics of design and engineering, where information can often be incomplete and inaccurate, and the frameworks fail to acknowledge that data only become available progressively as the experiences with outsourcing and offshoring increase. Given that GPD is a relatively recent trend, the opportunity to draw on previous experience is reduced and the availability of information is often limited and hence, the notion that decision-making processes should rely heavily on the availability of information is somewhat paradoxical in the context of GPD.

To summarise, rational decision-making presupposes that information is available (Citroen 2011), whilst GPD decisions are characterised by their high degree of uncertainty, limited available information and often rely on previous experience. Therefore, there is a need to better understand the types of information required by management when making decisions in GPD to better support the decision-making process.

3.3 Decision-Making in Global Product Development

In comparison with areas such as manufacturing and IT services, decision-making in GPD is a relatively unexplored topic. However, during several case studies with Danish manufacturing companies, over 50 decisions were observed when outsourcing and offshoring parts of PD (Søndergaard and Ahmed-Kristensen 2016). The key findings are briefly outlined here:

- The broad variety of information sources used at the companies indicated the complexity of decision-making in GPD, and the information used was often context specific. For offshoring decisions, existing global footprint and market information were key information sources used to support the decisions. For outsourcing decisions, control over activities, core competencies and product/process requirements were key information sources used to support the decisions.
- Most of the studied companies revealed a lack of methods in place for supporting the decision-making process, and hence, the majority of decisions were made on an ad hoc basis. This was particularly common for decisions related to location of new development sites and decisions related to setting up distributed PD teams.

The unstructured and ad hoc manner in which the decisions were made during the study implies that there is a requirement to support the decision-making process in GPD. Decisions made in such an ad hoc manner have been characterised as sporadic decisions by Cray et al. (1988) and often result in an informal and lengthy decision process, which was also reflected in the studied companies.

The findings from the study highlight the need for a more structured approach to strategic decision-making in GPD that supports management and decision-makers in identifying relevant information for specific decision types and encourages the use of practical methods that support implementation of the decisions.

3.4 Recommendations for the Development of a Decision-Making Process in Global Product Development

Based on their study investigating decision-making in GPD, Søndergaard and Ahmed-Kristensen (2016) provide recommendations towards the development of a structured decision-making process. The recommendations aim to support a shift from the observed ad hoc decision process to a more *informed* decision process, and as such, the input of information to support the specific decision types is critical. The information inputs during the decision-making process are derived from two sources: (1) the information that the decision-makers put into the decision and (2) the empirical findings from their study investigating decision-making in GPD (Søndergaard and Ahmed-Kristensen (2016). Adopting this approach enables individualised decisions to be made based on the knowledge and experience of the decision-makers, whilst also incorporating the information and methods used for the specific decision types identified in the previous section. Five recommendations for the development of a structured decision-making process for GPD are outlined:

1. *Decision definition* the decision-maker(s) identifies and forms agreement in relation to the key issues that need to be addressed, i.e. which PD activities to outsource and which to offshore.

2. *The key drivers* the key motivation(s) for the decision is identified, i.e. reductions in PD costs, access to new competencies, or closeness to global production facilities. Examples of motivations from previous studies investigating GPD (Søndergaard and Ahmed-Kristensen 2016) are provided to support this process.
3. *Scenario development* key scenarios describing the potential consequences of the decision are mapped, and these support decision-makers in highlighting any missing information for making the decision. This allows decision-makers to proactively identify potential challenges and hence develop precautionary strategies to avoid deviations.
4. *Uncertainty reduction* methods to support the implementation of the decision are identified. Key methods identified during Søndergaard and Ahmed-Kristensens study (2016), such as risk assessments, design reviews or vendor selection methods, are provided to support this process. However, decision-makers can also apply other methods that are deemed appropriate for the specific context and decision.
5. *Decision action* a strategic action plan is developed, including the key drivers for the decision, any missing information and potential challenges as a result of the decision and the methods adopted to support the implementation of the decision.

Once the decision is made, it is important to monitor and measure the impacts that outsourcing or offshoring parts of PD have at the company to encourage an organisational learning approach to GPD. Monitoring the impacts enables management to make adjustments along the process and hence, avoid any deviations as a result of common challenges encountered during GPD. The following sections focus on the development of performance measures in the context of GPD.

4 Performance Measurement

Although performance measurement (PM) is a well-established concept for business processes in general, with several comprehensive studies exemplifying PM as a practical tool to support decision-making (Kaplan and Norton 1996; Neely et al. 2000), there has been less focus towards PM in the context of GPD. The following sections aim to address this by adopting theoretical concepts from PM system design to investigate PM in the context of GPD. A framework to support the development of key performance indicators in GPD is developed, and its application is exemplified in two Danish manufacturing companies.

4.1 Performance Measurement System Design

Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals (Neely et al. 2000). The measurement of performance requires a PM system, with the critical element being a balanced set of financial and non-financial key performance indicators (KPIs), which in this chapter are defined as quantifiable metrics that help an organisation measure the success of critical factors. Given the centrality of KPIs in a PM system, ensuring purposeful and measurable KPIs are developed is critical. During their work on PM system design, Neely et al. (2000) propose six desirable characteristics for developing successful KPIs:

1. Indicators should be derived from the company's strategy.
2. The purpose of the indicator must be made explicit.
3. Data collection and methods of calculating performance must be clear.
4. All stakeholders must be involved in the selection of the indicators.
5. The indicator should take account of the organisation.
6. The indicators should change as circumstances change.

Although the characteristics are intended for the development of KPIs for business processes in general, they also offer indication towards what constitutes a 'good' KPI for PM in environments such as GPD.

4.2 Key Performance Indicators: Leading and Lagging

During the development of the balanced scorecard, Kaplan and Norton (1996) identified two types of KPIs important for performance measurement:

- Lagging KPIs: that measure output of past activity and typically consist of financial indicators.
- Leading KPIs: that measure factors influencing a process and are drivers of performance.

Lagging KPIs (outcome measures) without leading KPIs (performance drivers) do not communicate how the outcomes of a process are to be achieved. For example, Taylor and Ahmed-Kristensen (2016) describe observations at a large Danish pharmaceutical company that were in the process of developing a new syringe. It was communicated at the beginning of the development project that the time to market for the new syringe was critical to avoid the risk of their component suppliers developing and releasing a similar product. Based on this understanding, the project manager and team identified the time taken for documentation approval by the internal approval committee for the project as a key factor that could lead to project time delays and hence, delay the time to market for the product. Therefore, 'The time-taken for document approval' was developed as a leading KPI to monitor this and prompt the team to take action when the expected approval time for project documents was exceeded. Furthermore, 'The number of days delayed due to document approval' was set up as a lagging KPI to measure the impact in relation to the projects time to market.

When developing leading KPIs, Rhodes et al. (2009) state that 'contrary to simple status oriented measures typically used on most projects, leading indicators are intended to provide insight into the probable future state, allowing projects to improve the management and performance of complex programs before problems arise'.

Despite the importance of developing KPIs to evaluate the outcome of a process (lagging KPIs), and KPIs to enable the course of action to be altered (leading KPIs), a recent study investigating PM in GPD highlighted how leading KPIs in particular appeared to be illusive in practice (Taylor and Ahmed-Kristensen 2016). In fact, a general criticism towards KPIs in engineering design is they tend to be lagging in nature and focus on the more tangible outcomes of the PD process such as return on investment or break-even time (Tatikonda 2007). However, measuring the outcome of GPD alone does not provide the predictive insight required to avoid deviations along the process. For example, Taylor and Ahmed-Kristensen (2016) observed that lagging KPIs did not provide feedback regarding challenges encountered during GPD, such as cultural differences and team proximity, which influenced the success and resulted in project time delays. In environments of high uncertainty such as GPD, identifying key challenges and developing leading KPIs accordingly is an important step to support the development of precautionary strategies and hence, avoid deviations along the process.

The following sections outline the development and application of a method to support the development of KPIs for GPD.

4.3 The Development of Key Performance Indicators for Global Product Development

In this section, the KPI Development Toolkit is presented, which was developed by adopting well-established methodologies for PM (Kaplan and Norton 1996; Neely et al. 2000) and utilising key findings from a research project that investigated PM in GPD (Taylor and Ahmed-Kristensen 2016). The KPI Development Toolkit aims to support project managers in manufacturing companies to develop and implement leading and lagging KPIs in GPD. The methodological framework for the toolkit consists of three phases that are carried out for 5 hours facilitated KPI development workshop. The three phases are summarised here.

Phase 1: Key concepts

Aim Develop an understanding towards key theoretical concepts of performance measurement.

Process The facilitator uses examples of best practice to develop an understanding towards the development and application of KPIs; PM to support decision-making; and the relationship between leading and lagging KPIs. It is important that key stakeholders involved with GPD at the company are involved at this phase to ensure the purpose of PM is understood.

Outcome Commitment from the GPD team towards developing and using KPIs.

Phase 2: KPI development

Aim Provide a structured approach for developing both leading and lagging KPIs.

Process The approach for Phase 2 follows the methodological framework illustrated in Fig. 1. There are three levels of PM illustrated in the framework, namely Business-level; Project-level; and Task-level, and coherence between KPIs developed at each level is important to encourage behavioural alignment at the company. The toolkit focuses on developing KPIs at the Project-level where less has been reported in the literature.

The methodological framework contains three key steps. First, key motivations and challenges for the GPD project are identified and prioritised and the cause–effect relationships between (1) key motivations that represent the desired outcome for the project and (2) key challenges that influence the success towards this outcome are identified and mapped to a cause–effect fishbone diagram (Kitcher et al. 2013). Strategies to prevent the influence on success are developed to support the development of quantifiable KPIs. Based on the strategies, leading KPIs are developed to avoid the identified influence on success and support the identification of

Fig. 1 Methodological approach for the development of leading and lagging KPIs

deviations along the process. Lagging KPIs are developed to measure the achievement towards the desired outcome. The strategies and KPIs developed are mapped to the companies PD process, indicating where along the process the strategies require implementing and the frequency of measurement for the developed KPIs. Phase 2 should involve key stakeholders from the GPD project and be repeated at important intervals during the project to ensure the KPIs change as the circumstances change.

Outcome Critical factors are identified and preventative strategies are developed and aligned with the PD process to support the development of measurable KPIs.

Phase 3: Reporting

Aim Support the documentation and implementation of leading and lagging KPIs.

Process Each of the developed KPIs is documented according to a KPI Template. The criteria in the KPI Template are based on previous templates for documenting KPIs (Neely et al. 2000) to ensure: the purpose and formula for measuring the KPI are understood; the main respondent for the KPI is outlined; and the frequency of measurement and targets are clearly defined. Following this, the KPIs are documented according to a KPI Visualisation Board, which allows for simple monitoring of both leading and lagging KPIs and provides indication towards key challenges, proposed solutions, key achievements and the next steps for measurement. The main respondent for monitoring the KPIs in the GPD project should be involved during Phase 3.

Outcome The KPI Template and KPI Visualisation Board are completed for monitoring the KPIs.

4.4 Application of the KPI Development Toolkit

The key results for the implementation of the KPI Development Toolkit at two large Danish manufacturing companies are presented in the following section (see Table 1 for company characteristics).

A 5-hour KPI development workshop was held at each of the companies with the aim to establish KPIs for the GPD projects. Prior to the

Table 1 Key characteristics of companies for the application of the KPI Development Toolkit

Characteristics	Company A	Company B
Employees	420 (global)	900 (global)
Industry	Air conditioning and refrigeration systems	Satellite communications for aviators
Offshore R&D facilities	China	South Africa
GPD project	Develop a software program to ensure future PD projects follow a standard process	Develop a new radio system for airplanes to improve communication when airborne
No. of KPI workshop participants	6	8

KPI development workshop, the project team from both companies had no experience with developing KPIs, and hence, clarifying key theoretical concepts in relation to leading and lagging KPIs during Phase 1 was particularly insightful. Phase 2 was the most time-consuming phase of the workshop, taking approximately 3 hours to complete. This was primarily due to the difficulties experienced during the prioritisation of key challenge factors in the GPD projects as many of the project team came from different functional backgrounds. For example, in company B the project manager felt the lack of commitment towards standard company procedures was a key issue likely to impact the project delivery time. However, the software engineer felt the lack of alignment between software and hardware development would result in quality issues. Despite the lengthy discussions, Phase 2 of the workshop was undoubtedly the most valuable for both companies as it supported the alignment of expectations within the project teams. Figure 2 illustrates an excerpt from the fishbone diagram completed at company B during Phase 2. Firstly, the project manager derived the desired outcomes for the project based on the organisation-level KPIs at the company. Secondly, the project team agreed that the lack of understanding towards key company procedures was the most critical factor influencing success of

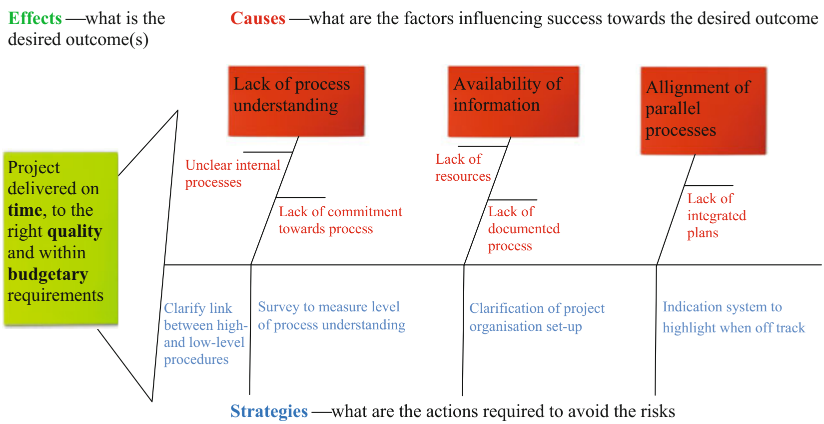

Fig. 2 Example of identifying key cause-effect relations and developing strategies at company B

the GPD project. Finally, it was decided that an internal company survey, focused on testing the level of understanding towards company procedures within the project team, should be developed to identify areas for improvement.

The project team considered the survey a powerful evaluation tool to capture data over time and monitor the level of understanding towards company procedures. However, it was critical the questions in the survey were carefully devised to ensure the results provided a true reflection of understanding towards key company procedures for the project in hand. As such, it was not possible to develop the internal company survey during the KPI development workshop as key decisions regarding the content of the survey needed approval from the quality assurance team. This hindered the opportunity to fully complete the KPI Template in Phase 3 (see Fig. 3). Without the questions in the survey, it was difficult to identify the key targets for the KPI. This was also the case for company A, where the strategy they developed required additional time outside of

Key Performance Indicator:	**Level of understanding towards company procedures**
Purpose	Increase level of understanding of processes and planning
Action plan	Develop 5 minute survey to tests level of understanding towards company procedures - distribute on regular basis
Critical influence factor related to	Process awareness and adherence at the company
Desired outcome related to	Improve level of understanding and adherence towards common processes supports achieve desired customer requirements, cost and time
Calculation (%of, #of, $of, ...)	Scaling system based on survey - expected % of correct answers Vs actual % of correct answers
Forcasted target (weekly/ monthly)	To be decided
Maximum target (weekly/ monthly)	To be decided
Measurement frequency	Monthly - the results are to be shared within the teams
Product development stage	Continuous—beginning of each stage of the PD plan
Data source	Participant results from survey
KPI type (Leading/ Lagging)	Leading - identifies where there is a lack of understanding towards processes and hence, allows for corrective action along the process
Main responsible	Program management office
Additional comments:	Different members have different understanding towards processes - requirement for answers in survey to be weighted Results from the survey should be populated digitally to ensure a database can be created and analysed over time

Fig. 3 Example of completed KPI template at company B

the 5-hour KPI development workshop, and hence, key targets for the developed KPIs could not be set.

To summarise, although the identification and prioritisation of key cause–effect relationships in Phase 2 was the most time-consuming step in the KPI Development Toolkit, it supported in aligning expectations for the GPD projects across key project stakeholders. Furthermore, designing strategic action plans was an important step to support the development of quantifiable, leading KPIs to measure intangible influence factors. However, the design and implementation of strategic action plans exceeded the time allocated for the KPI development workshop in both company A and company B. Therefore, Phase 3 in the KPI Development Toolkit should not be completed until the strategic action plans are implemented to ensure key targets for the KPIs are determined.

5 Conclusions

The chapter aims to unravel some of the supporting processes to create high value engineering networks through open innovation and through globalising (offshoring and outsourcing) parts of the engineering functions in a product development process. The motivations for the global product developments processes are now relatively well understood in research, yet these bring their own challenges. To support firms in evaluating, selecting and monitoring global product development processes, cases studies were discussed to highlight the sporadic nature of decision-making and the lack of understanding of key performance indicators, which can successfully monitor and address these challenges. Offshoring decisions, which typically are the approach for the earlier and higher value elements of the engineering value chain, were found to be made in an ad hoc manner with complex level of information needed, and a lack of relevant method to support these types of decision added. A framework to monitor the impact of these decisions is presented, focusing on both reducing the risk and monitoring for success, with key performance indicators developed specifically for globalised product development. The importance of creating, for example, the appropriate cultures, appropriate IT infrastructure and understanding the impact of virtual platforms to support open innovation was highlighted.

This chapter contributes to understanding the challenges of open innovation in high value engineering networks; making decisions to globalise the higher value phases of the engineering value chain (product development process); and monitoring the impact of these decisions (global product development processes). For each of these initial recommendations and frameworks are suggested to increase the likelihood to obtain success.

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