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GLOBAL PRODUCT DEVELOPMENT: KPI SELECTION SUPPORT

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1. Introduction

The migration from collocated, cross-functional product development (PD) to a form of Globally Distributed PD (GPD) represents a major transformation in industry. This is particularly evident when managing PD projects with globally distributed teams, as cultural diversity and team proximity accentuate difficulties traditionally found in conventional PD projects [Anderson and Parker 2012, Hansen and Ahmed-Kristensen 2011]. To effectively manage GPD projects, the selection of Key Performance Indicators (KPIs) is recommended, which enable the discovery of deviations early on and support managers to resolve problems when they arise [Christodoulou et al 2007, Hansen and Ahmed-Kristensen 2012]. The selection of KPIs has been investigated in the operations management field from a business process perspective [Kaplan and Norton 1996, Neely et al 2000]. However, research on KPIs in the field of engineering design is relatively sparse, particularly when tasks and activities are globalised.

In this paper, we develop an understanding toward the selection and use of KPIs in GPD projects informed from the findings of two in depth case studies conducted with large Danish manufacturing companies. Based on the findings a framework was developed, which provides a process to: address the selection of KPIs specifically for GPD; support the selection of both Leading and Lagging KPIs and; minimise the impacts as a result of the challenges in GPD in addition to KPIs selected that are goal-oriented. The framework was tested and evaluated in a third company and initial results indicate the tool supported the selection of Leading and Lagging KPIs, which resulted in preventative actions being implemented at the company. Furthermore, the framework supported in aligning the interests of cross-functional team members involved in the project.

2. Literature review

The literature reviewed draws on two fields, namely; the globalisation of tasks and activities in the field of engineering design and the selection of KPIs in the operations management field.

2.1 Global Product Development

Many Western companies have begun to globalise parts of PD, the first being manufacturing activities with design activities following. GPD is the globalisation of tasks and activities throughout the PD process, from the early concept development phase and detail design through to the final testing of prototypes. The decision to globalise parts of PD is a consequence of an increasingly competitive world market as companies look to reduce development costs, access new resources and get closer to their global market. However, difficulties of coordinating tasks and activities in GPD projects in comparison to conventional PD have been highlighted as cultural diversity and team proximity accentuate factors influencing success [Anderson and Parker 2012]. Table 1 highlights key challenges and motivations observed in GPD from case studies conducted in the manufacturing industry. Companies often pursue GPD to reduce costs by utilising low labour costs in regions such as India and China. However, recent work found that companies pursue GPD for other reasons than those directly related to cost reductions [Eppinger et al 2009] and less tangible benefits, such as increasing access to new technologies or improving flexibility in operations become significant. Previous studies indicate that companies adopt a learn-by-doing approach to GPD when dealing with challenges, such as those in Table 1, with solutions to managing the impacts on PD implemented on an ad-hoc basis. This can be costly further down the PD process. For example, studies by Hansen and Ahmed-Kristensen [2011] discovered that companies only considered positive impacts of moving abroad, leaving few processes in place to handle the difficulties. Solutions to these difficulties were implemented on an 'as-needed' basis and at times resulted in design rework and project time delays. Barthelemy [2003] highlights the need to understand the hidden costs as these impact the success of GPD and challenge the decision rationale. To better manage these difficulties there is a requirement for practical frameworks that support management when making decisions in GPD projects [Eppinger and Chitkara 2009]. More specifically, selecting KPIs in GPD that provide managers with continuous feedback along the process is recommended to allow deviations to be discovered early on [Hansen and Ahmed-Kristensen 2012].

Table 1 Key challenges and motivations in GPD

Key challenges [Hansen and Ahmed-Kristensen 2012]	Key motivations [Christodoulou et al 2007]
Cultural differences	Access to new resources
Lack of common vision	Increase customer base
Documentation	Cost reductions
Alignment of interfaces	Reduce time to market
IP rights and security	Risk mitigation
Knowledge sharing	Flexibility & Scalability
Standardising tools & processes	

2.2 The selection of Key Performance Indicators

Research on KPIs in engineering design is sparse, particularly when tasks and activities are globalised. However, the operations management field provides a theoretical basis to investigate the selection and use of KPIs. In this context, KPIs are defined as quantifiable metrics that help measure the success of identified critical factors. Kaplan and Norton [1996] classify KPIs within two categories:

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

The selection of Leading and Lagging KPIs must be balanced. Lagging KPIs (outcome measures) without Leading KPIs (performance drivers) do not communicate how the outcomes of a process are to be achieved. Leading KPIs focus on monitoring the factors influencing success of a process and can inform management of where to make adjustments along the process. However, a general criticism of KPIs in PD is they are Lagging and provide a time-delayed retrospective look on performance, rather than an instantaneous evaluation or predictive insight required to make adjustments along the process [Tatikonda 2007]. Neely et al [2000] propose six criteria for selecting KPIs. These are: (1) KPIs should be derived from company strategy, (2) The purpose of the KPI must be made explicitt, (3) Data collection and methods of calculating performance must be clear, (4) All stakeholders must be involved in the selection of the KPIs, (5) The KPIs should take account of the organisation and (6) the KPIs should change as circumstances change. In project management literature for PD there is agreement that KPIs should be selected according to key performance dimensions: Development Time, Cost and Product Quality [Hoegl et al 2004]. Additional frameworks to support the selection of KPIs include work by Neely et al [2000] on performance measurement system design and the

Balanced Scorecard by Kaplan and Norton [1996]. However, the two frameworks support the selection of KPIs at a business-level and provide little support for selecting KPIs at a project-level in the context of GPD.

In sum, there is a lack of research that focuses on the selection and use of KPIs in GPD projects. Selecting Lagging KPIs alone provides a time-delayed, retrospective look on performance. In GPD projects where factors influencing success are accentuated, there is a requirement to monitor these to inform management of when to make adjustments along the process. Based on this review, the research aim and approach is described in the following section.

3. Methodology

3.1 Research aim and approach

The aim of the research was twofold: first to develop an understanding towards the selection and use of KPIs in GPD projects and second; to develop and test a tool that provides a structured approach for selecting and reporting KPIs in GPD at a project level. Two in depth case studies with large Danish manufacturing companies were conducted with a focus on two GPD projects. These provided the necessary understanding of real time tasks and activities to address the first aim [Voss et al 2002]. For the second aim, the results from a third company case, where the tool was tested, are presented and described in Section 5: Tool development.

3.2 Description of case studies

Company A and B represent two large Danish manufacturing companies with recently established global R&D sites in India and China (see Table 2 for company and project characteristics). A high involvement of the global R&D sites with engineering design activities was a key criterion for selection to allow for comprehensive investigations of GPD projects.

3.2.1 Company A: Project I

The company specialises in the production of industrial valves and controls for the refrigeration and air conditioning markets. In 2011, the company established an offshore R&D department in India with the key motivation to reduce costs by gaining access to low labour costs of skilled engineers in India. However, the Danish engineers experienced difficulties with the Indian engineers and a number of tasks and activities were neither completed on time nor to the desired quality. The motivation of the Indian engineers towards the tasks, which were routine in nature, was seen as a contributing factor to these difficulties and therefore, a lead engineer in Denmark involved the Indian engineers as the "main drivers" in a more complex PD project, referred to here as Project I. The project involved 10 experienced mechanical engineers from India and Denmark and forms the basis for the results reported in this paper for Company A. The objective was to improve the performance of an existing valve range by increasing the product lifetime. The project was introduced as a "Pilot" project and the solution was known by the Danish engineers with the primary aim to improve the collaborations, whilst keeping risk low. The project followed the company's standard PD process for PD projects (Figure 1).

Figure 1 Standard product development process at Company A

3.2.2 Company B: Project II

The company specialises in the development and manufacture of blood analysis instruments, such as blood gas analysers and syringes for the pharmaceutical industry. The company had recently established an offshore R&D department in China with the key motivation to reduce costs by gaining access to skilled engineers in low cost regions. From the beginning of the collaboration, the Chinese R&D were introduced to Project II in the Product and process design phase at the company (see Figure 2 for PD process followed). The project involved 14 mechanical engineers from China and Denmark and forms the basis for the results reported in this paper for Company B. The aim of Project II was to develop a new blood gas analyser that performed at a higher speed than those currently on the market. The product to be developed was complex, including 15 different modules, with the project team organised according to these modules to allow for the global segregation of design tasks.

Figure 2 Standard product development process at Company B

Table 2 Characteristics of Company A (Project I) and Company B (Project II)

Characteristics of companies	Company A (Project I)	Company B (Project II)
Industry sector:	Refrigeration & air conditioning	Pharmaceutical
Product to be developed in project:	Industrial valve	Blood gas analyser
Expected duration of PD project (before production):	4 months	4 years
Offshored R&D site involved in project:	India	China
Years offshored R&D established at time of study:	2.5	1.5

3.3 Data collection and analysis

The empirical results presented in the following section are based on 43 hours of direct, longitudinal observational studies, 21 semi-structured interviews and the analysis of company documentation (Table 3); allowing for triangulation of the results, which strengthened the reliability and validity of the findings. The observations took place during key project meetings over a period of eight months at Company A, from Business case to Testing (Figure 1), and three months at Company B, during Product and process design (Figure 2). The researchers did not actively participate during these observations. Field notes were taken, which were structured according to the research aims of this paper and transferred into a coding scheme for further analysis. Despite the observation of fewer phases in Project II than Project I at Company B, interviews and document analysis enabled the projects to be investigated retrospectively. The semi-structured interviews lasted ca. 60 minutes, with interviewees selected based on their involvement in the GPD projects under investigation. The questions related to: the motivations and challenges in the GPD projects; the impact of these on PD and; the KPIs used for monitoring performance. The interviews were audio recorded, transcribed and transferred into a predefined coding scheme for further analysis. The coding scheme was developed based on the literature review where possible. However, given the relatively sparse research on the selection of KPIs in GPD projects, codes were also generated from the empirical studies to avoid the confinement of data and added to the predefined coding scheme. The coding scheme consisted of three main elements: The challenges and motivations in GPD, the impacts on GPD projects and the KPIs selected. The KPIs were classified within the performance dimensions Development Time, Cost and Product Quality. KPIs that could not be classified were placed in an "Other" category. The analysis of code co-occurrence indicated key patterns within the data and provided an understanding of the rationale and theory underlying relationships. Documentation related to detailed project plans, risk assessments and key project metrics were collected and analysed qualitatively.

Table 3 Characteristics of data collection methods

Characterisitics of data collection	Company A	Company B
Interviewees' positions:	Senior Mgt., Program Mgt., Mechanical engineers	Senior Mgt., Program Mgt., Mechanical engineers
Nr. of interviews:	11 interviewees	8 interviewees
Hrs. of observations:	26	17

Analysis of documents	Project plans, Risk assessments, Project metrics, meeting minutes	Project plans, Risk assessments, Project metrics, meeting minutes

4. Findings

The empirical observations presented in this section in Company A and B were made without intervention and address the first aim of this paper. The process for selecting KPIs in Project I and II is described here and the resulting KPIs are presented. The key challenges encountered in the projects are further exemplified.

4.1 KPI selection process

In Project I, a structured approach for selecting KPIs was not followed; rather the KPIs selected at a project-level were largely based on the experience of the project manager. However, the tasks undertaken in the Business case phase at Company A assisted the project manager in setting budgetary requirements, project schedules and predefined product quality requirements for the project, which were aligned with high-level KPIs at the company. Similarly, project-level KPIs were to adhere with high-level KPIs in Company B such as: Project schedule and Costs, Customer satisfaction and Product quality. To further support the selection of project-level KPIs, a KPI selection workshop was held in the Project initiation phase of Project II, with the high-level KPIs as the starting point. The primary approach for selecting KPIs during the workshop was a brainstorming session within the project team where members were asked to select KPIs they would like to work with in Project II, whilst adhering to the high-level KPIs at the company. However, there was a lack of experience and understanding of the purpose within the project team toward selecting and using KPIs and the project manager experienced difficulties with gaining commitment. Only a few members of the team actively participated in the brainstorming session. The limitations of such approaches when selecting KPIs have been highlighted in literature [Barr 2014]. Furthermore, the importance of including all project members when selecting KPIs is described as a key characteristic when designing KPIs [Neely et al 2000]. Such involvement enables KPIs to be selected according to the interests of stakeholders, which is important for gaining commitment. Despite this, the global R&D was not involved in the selection process in both companies.

4.2 KPIs in the GPD projects

Table 4 presents KPIs selected in Project I and II according to performance dimensions typically found in project management: Development Time, Cost and Product Quality. It was possible to classify the majority of the selected KPIs according to these dimensions, with the exception of four "Other" KPIs, which could not be directly classified. This can largely be explained given the adherence to the high-level KPIs during the selection of project-level KPIs in both projects, which related to project costs, time schedules and product quality objectives. Many of the KPIs selected relate to Development Cost and represent financial KPIs (Lagging KPIs), which have been described as measuring the output of past activity, rather than monitoring the impacts on a process (Leading KPIs) [Kaplan and Norton 1996]. Considering the primary motivation for the collaborations in both projects was to reduce costs, these financial KPIs can be expected. Furthermore, selecting financial KPIs is common as these are more tangible and easy to measure. These findings demonstrate that KPIs related to performance dimensions in project management are also important when evaluating the success of GPD projects. However, these have been described as providing a time-delayed retrospective look on performance [Tatikonda 2007] and are Lagging in nature, rather than instantaneous measurement or predictive insight required to avoid the challenges in GPD i.e. Leading in nature. The four "Other" KPIs in Table 4, which could not directly be classified according to performance dimensions in project management, were important in the projects and were a result of identified project challenges related to: a lack of common vision in the teams and poor documentation. However, on occasions, the "Other" KPIs were used as Lagging KPIs and provided time delayed information towards the impacts on the projects. For example, despite a lack of common vision being identified in the Project clarification phase of Project I as a factor impacting project success; a KPI was not selected to monitor this during the KPI selection process. Rather, the KPI Internal design expert feedback was used after a lack of common vision had occurred in the Detail design phase, providing time delayed information toward the challenge. This is further exemplified in the following section. In Project II, it was identified during the KPI selection workshop that the time taken for project documents to be approved internally was a challenge that could result in project time delays. Given adherence to project schedule was an important high-level KPI for the project, the KPI Documentation approval time was selected as a Leading KPI in the project to monitor this and make adjustments along the process if approval time was to be delayed. Furthermore factors impacting the success of the Lagging KPIs, such as Project lead time, were identified and activities were set up to prevent missed deadlines. Although the "Other" KPIs in Table 4 do not directly measure Development Time, Cost and Product Quality; they monitor factors that impact the success of these performance dimensions, such as a lack of common vision and documentation issues, and identifying such challenges early in GPD projects and selecting and documenting KPIs that monitor them is important to avoid the impacts.

Table 4 Selected KPIs and definitions according to performance dimensions in Project I and II

Performance dimensions in PD projects	Key Performance Indicator selected in GPD projects	Definition	Project I	Project II
Development Cost	Cost of Product Development	Estimated resources required for product development	x	x
	Return on investment	Yearly cost savings after investment	x	x
	Planned Vs Actual resources	Expected resources used in comparison with actual used	x	
	Total project cost	Estimated reources required for product development		x
	Cost of delay	Financial implications of project delays		x
Development Time	Project lead time	Amount of time from project initiation to completion	x	x
Product Quality	No. of product lifecycles	Durability of the product	x	
	Customer satisfaction	Usability of product prototypes	x	x
Other	Documentation errors	Number of errors found in drawings completed by global R&D	x	
	Documentation approval time	Time taken to approve documents by internal approval board		x
	Internal design expert feedback	Feedback from design experts at company, external from project	x	
	Supplier feedback on assembly	Feedback from supplier early in product design phases of project	x	x

4.3 A lack of common vision in the GPD projects

A lack of common vision within the team was a key challenge encountered in the GPD projects, which resulted in design rework and project time delays. As stated earlier, Project I was introduced to the Indian engineers as a "Pilot" project with the aim of improving collaborations. As such, the Indian engineers invested a large amount of time and resources in the early phases of the project and proposed a number of solutions, which would potentially add value to Project I and impact additional product variants outside of the project. These propositions were rejected in the Detail design phase of the project when using the KPI: Internal design expert feedback, as they did not fit within the scope of the solution the Danish engineers had in mind. This resulted in confusion amongst the Indian engineers in relation to the project expectations and caused design rework and contributed to the project being delayed by two and a half months. A lack of common vision within the team was identified as a factor impacting project success when conducting the project risk assessment in the Project clarification phase of Project I. However, the KPI: Internal design expert feedback was used late in the process as a Lagging KPI and provided time-delayed information in relation to the lack of common vision. Hence, the KPI did not provide the predictive insight required in order for necessary intervention action to avoid project time delays. A Leading KPI, described as KPIs that monitor factors impacting a process [Kaplan & Norton 1996], was not selected to monitor the lack of common vision. In Project II, a lack of common vision was encountered during the design development phase, which resulted in design rework. In Project II, key decisions regarding the design for the gas analyser were already made when the Chinese engineers were introduced and the main design was fixed. This routinised the development tasks and reduced project uncertainty, leaving little manoeuvrability for design changes by the Chinese engineers. However, early in the collaborations, the Chinese R&D expressed their willingness to work on complex development tasks. This resulted in design re-work as when the Chinese engineers attempted to improve their individual product modules, they discovered that the Danish engineers had already attempted the same improvements unsuccessfully. Such scenario was demotivating for the Chinese engineers as innovative freedom was reduced. The lack of common vision in the project was not highlighted as a key challenge during the KPI workshop and a Leading KPI was not selected to monitor this to allow the avoidance of design rework. Involving the global R&D during the KPI workshop may have highlighted this challenge at an early phase with the importance of involving all stakeholders in the selection process highlighted in literature [Neely et al 2000]. A lack of common vision or shared understanding is also a common challenge in conventional PD, however similar studies describe how team proximity and cultural differences accentuate this [Anderson and Parker 2012, Hansen and Ahmed-Kristensen 2011] and the impacts on GPD projects require monitoring.

Considering the first aim of this paper, an understanding has been developed in relation to the selection and use of KPIs in GPD projects. To summarise, the approach adopted for selecting KPIs did not provide sufficient structure to select and document Leading KPIs that monitored the challenges in the GPD projects. KPIs selected according to Development Time, Cost and Product Quality are important for GPD projects. However, there is a requirement to balance these with Leading KPIs, which monitor the factors impacting success toward the performance dimensions (such as the challenge factors in Table 1). This will provide accurate and timely feedback to support (and if necessary adjust) decisions along the process.

5. Tool development

This section describes the development of a tool that supports the selection of Leading and Lagging KPIs in GPD projects, which was developed based on the findings in the previous section. Initial testing and evaluation of the tool is described with a third company case.

5.1 The KPI Toolkit: Support for the selection of KPIs in GPD projects

Building on previous work in the field of GPD [Hansen and Ahmed-Kristensen 2012] and operations management [Kaplan and Norton 1996, Neely et al 2000], the KPI Toolkit aims to support project managers for selecting both Leading and Lagging KPIs at a project-level in GPD. Including a challenge-oriented approach to selection, the KPI Toolkit provides an alternative basis to design, select and document KPIs than those described in literature, encouraging the selection of Leading KPIs to monitor the factors impacting GPD projects. There are three phases to the KPI Toolkit, which support practitioners to prepare, stage and execute a KPI selection workshop:

- Phase 1 (Project team): Develops an understanding towards key concepts for selecting KPIs, e.g. the purpose and value of KPIs, the relationship between Leading and Lagging KPIs.
- Phase 2 (Project team): Provides a structured approach for selecting project-level KPIs according to critical impact factors in GPD.
- Phase 3 (Project Mgt.): Provides templates for the documentation of the selected KPIs.

Before using the KPI Toolkit, the experience with selecting and using KPIs in the project team and maturity of the GPD project are assessed to determine the starting phase in the toolkit, e.g. if key concepts for selecting KPIs are understood then Phase 1 can be skipped. Phase 1 and 2 require participation from key members of the project team and Phase 3 can be completed by the project manager alone. The time required to complete all three phases is ca. 5 hours with the majority of time allocated for Phase 2: KPI selection. The core elements to Phase 2 are illustrated in Figure 3. The framework highlights three levels of performance measurement: the business-unit level, the project-level and the task-level and KPIs selected at each level must be coherent. In this paper we focus on KPI selection at the project-level. The following key steps are conducted in Phase 2:

- First, key motivations and challenges for the GPD project are selected (according to those in Table 1), prioritised and mapped to a cause-effect Fishbone diagram [Ishikawa 1990]. The Fishbone diagram is used to identify possible factors impacting the success of a specific event or desired outcome and has been adopted by researchers attempting to understand the effects of outsourcing in general [Kitcher et al 2013]. Strategies to prevent the impacts as a result of the challenges and achieve the motivations are then planned and prioritised. Leading KPIs are designed for monitoring the activities as a result of the selected challenges and their impacts on success, and Lagging KPIs to evaluate performance towards the selected motivations.
- Second, the activities are mapped to the company PD process with indication of where along the process the selected KPIs require monitoring.
- Third, the selected KPIs are reported in a KPI template, which includes information related to the Purpose of the KPI, the challenge or motivation it relates to, the main responsible for the KPI and the frequency of measurement and targets.

Phase two of the KPI Toolkit is reviewed at important project intervals, such as after key milestones in the PD process to ensure the KPIs change as project circumstances change.

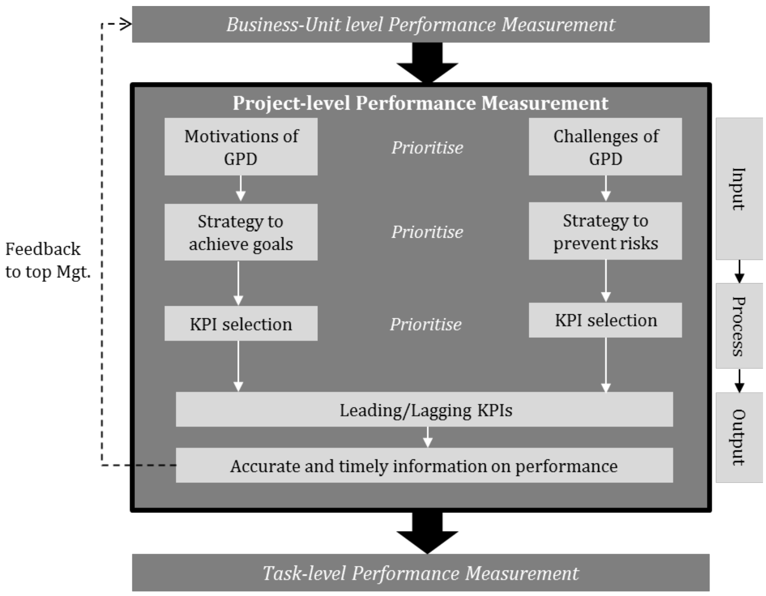

Figure 3 Framework to support the selection of Leading and Lagging KPIs in GPD projects

5.2 Testing

The KPI Toolkit was tested in a large Danish manufacturing company that specialises in the production of ventilation and air handling systems in the marine and offshore sector. It was not possible to test the toolkit in a GPD project; however, the company were interested in testing the toolkit to set up KPIs in a software development project, which aimed to develop a common platform for conducting and documenting future PD projects at the company. Despite being a software development project, the project was expected to follow the standard PD process employed at the company from the early planning and conceptualisation through to the final testing and evaluation of the software. Six core members of the project from the mechanical engineering department participated in testing the KPI Toolkit, including general and top level management. When assessing the experience with selecting and using KPIs, the project team decided that all three phases of the KPI

Toolkit were required. The workshop lasted ca. 4 hours and was conducted during the early planning phase of the project. As a result of the workshop, key motivations selected and prioritised for the project were to: Reduce PD costs and Reduce time to market. The critical challenge factors impacting the success of these were selected, prioritised and identified as: a lack of common vision across functions at the company and communication problems within the project team. For the lack of common vision, plans were made to create a document where the level of acceptance in relation to the software being developed would be measured across functions. Two Leading KPIs were documented in the KPI template for monitoring the challenge factors impacting success, namely: The level of participation of key project members during project meetings and Alignment of interests across functions during the project, which were related to the Lagging KPIs: Product development cost and Product development time respectively. The key steps followed during phase 2 were documented in the templates developed to allow for the learnings to be passed to future projects at the company.

5.3 Evaluation

The focus for the evaluation was on the process for selecting KPIs in the KPI Toolkit and included a survey with all five participants, directly before and after the workshop. This was supplemented with interviews with two of the participants five months after the workshop to allow sufficient time for implementation. The evaluation was conducted following Kirkpatrick's approach as extended by Ahmed-Kristensen [2001]:

1. Reaction: The usefulness and applicability of the KPI Toolkit.
2. Learning: The increased understanding of the key concepts for the selection of KPIs.
3. Results: The difference between KPIs selected before and after the KPI Toolkit.
4. Validation: The improvements required to support the selection of KPIs.
5. Behaviour: The impact the KPI Toolkit had on everyday tasks and activities.

The survey focussed on the first four evaluation principles outlined above. Results were positive with mutual agreement from the participants that the KPI Toolkit supported the selection of Leading and Lagging KPIs, which were not in place prior to the workshop. Strategies were planned in order to prevent identified factors impacting project success with Leading KPIs selected to monitor these. To evaluate the impact on behaviour, interviews were conducted five months after the KPI Toolkit was tested. During the interviews, it was discovered that the start date for the project had been delayed and the selected KPIs had not yet been implemented. However, the planned strategies as a result of the workshop were underway with the KPIs expected to be implemented. Furthermore, the interviewees found that adopting the Fishbone diagram to identify critical factors impacting the success of the project supported in aligning the common vision within the project team, which is often a challenge experienced in non-collocated projects. In addition, by highlighting the impact factors that supported the formulation of the KPIs, the interviewees felt this increased the likelihood of team members accepting and using the KPIs. The knowledge gained during phase 2 of the KPI Toolkit, in particular the increased understanding of Leading and Lagging KPIs, had been used indirectly within the company and passed on to other projects. In their evaluation of the KPI Toolkit an interviewee stated:
"We have used the mind-set of not only measuring the end result but also how to improve the process as we go along… it really has impacted a lot on the way we approach and discuss KPIs, and also the structured way to identify and categorise has been very helpful", Project manager.

7. Conclusion

Research toward the selection and use of KPIs in engineering design, in particular when parts are globally distributed, is sparse. Two in-depth case studies with large Danish manufacturing companies with global R&D functions in India and China addressed this. The main findings highlighted the use of Lagging KPIs in the observed GPD projects, which were selected according to traditional performance dimensions found in conventional PD, namely: Development Time, Cost and Product Quality. However, the Lagging KPIs did not provide the predictive insight required to avoid challenges related to a lack of common vision, resulting in project time delays and design rework. Traditional performance dimensions commonly found in conventional PD support a goal-oriented approach to selecting KPIs, which are Lagging in nature, and is typically influenced by top-down company strategy. However, the GPD projects highlight the need for a challenge-oriented approach to selecting KPIs, i.e. in order to identify the challenge early in the process and minimise the impact of a lack of common vision on GPD project success. Based on these findings and building on previous work in the fields of operations management [Kaplan and Norton 1996, Neely et al 2000] and engineering design [Hansen and Ahmed-Kristensen 2012], a framework was presented and evaluated, which provides a process to: address the selection of KPIs specifically for GPD; support the selection of both Leading and Lagging KPIs and; minimise the impacts as a result of the challenges in GPD in addition to KPIs selected that are goal-oriented. The framework was tested with a third company case and initial results indicate the framework supported the selection of Leading KPIs, which resulted in preventative actions being implemented at the company. Furthermore, identifying critical factors impacting the success, prior to the selection of the KPIs, proved a valuable element of the framework and supported in aligning the interests of different parties involved in the project. It was not possible to test the framework in a GPD project, which is a limitation of the study. However, this is also a strength as it demonstrates the framework is transferrable across projects. Additional testing is required in the context of GPD for further validation. By building on previous research in GPD and adapting key aspects of methodologies from operations management, this paper has: developed an understanding of how KPIs are selected and used in GPD projects and; developed and tested a tool, which provides an alternative approach to design, select and document KPIs in GPD than those found in literature by incorporating a challenge-oriented approach to selection. In general, the study builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with multiple longitudinal observational studies, providing the basis for researchers and practitioners to develop practical tools in GPD.

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