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Exploring the 4I framework of organisational learning in product development: value stream mapping as a facilitator

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Organisational learning (OL) that enhances efficiency and the continuous improvement of processes is a key objective of lean product development and has become an important principle of new product development (NPD). Therefore, it is critical for an organisation to capture individuals' and groups' knowledge and learning about processes, institutionalise it, and deploy it organisation-wide. Since OL is more likely to occur if it is supported systematically, NPD scholars and practitioners recognise the importance of investigating facilitators' effect on OL. However, there is no shared understanding of OL among existing studies. This disparity makes it hard to assess, compare, and integrate prior findings into studies. Our article addresses this gap. We investigate how value stream mapping (VSM) and its implementation in NPD affect OL in development processes. Therefore, we operationalise OL on the basis of Crossan *et al.*'s 4I framework, which is comprehensive and widely recognised (Crossan, M., Lane, H. and White, R., 1999. An organizational learning framework: from intuition to institution. *The Academy of Management Review*, 24(3), 522–537). We analysed the approach to VSM and its implementation in four longitudinal, comparative case studies in the German-speaking car supplier industry. Using the 4I framework, we captured VSM's effects on the various OL dimensions. We provide valuable insights for R&D managers who seek to improve their processes and want to implement VSM.

Keywords: new product development; value stream mapping; organisational learning; continuous process improvement; efficiency

'[. . .] solving a problem, introducing a product, and reengineering a process all require seeing the world in a new light and acting accordingly. In the absence of learning, companies – and individuals – simply repeat old practices'. (Garvin 1993: 78)

Introduction

In an age of discontinuity, one of the few sources of sustainable competitive advantage is a firm's ability to develop new products effectively and efficiently (Womack *et al*. 1990, Caffyn 1997, Caffyn and Grantham 2003, Haque and James-Moore 2004, Baines *et al*. 2006). To achieve efficiency, firms must realign and adapt their development processes to ever-changing conditions. In other words, they must improve continuously. Continuous improvement, which is an inherent component of lean product development (Rother 2009), not only demands individual learning but also organisational learning (OL). Through OL, the organisation captures individuals', teams', and departments' knowledge and learning about processes, and institutionalises them (Bartezzaghi *et al*. 1997, Saban *et al*. 2000, Ruy and Alliprandini 2008). In the manufacturing environment, it has been proven that collective learning processes require training and exercise and are not learned immediately (Van Eijnatten and Putnik 2010). Also in new product development (NPD) processes, OL is more likely to occur if it is supported systematically. The literature offers case studies that identify a number of OL facilitators: post-project audits to learn from completed projects (Bartezzaghi *et al*. 1997, Koners and Goffin 2005, 2007, Goffin and Koners 2008, Ruy and Alliprandini 2008, Goffin *et al*. 2010), stage-gates or review sessions such as design reviews or quality audits to reflect on process strengths and weaknesses from which ideas for improvement can be drawn, feed-forward planning processes such as best practice case studies (Jayawarna and Pearson 2003), and learning points shared by team members (Caffyn and Grantham 2003) to correct errors and, thus, trigger learning cycles during a project (Ruy and Alliprandini 2008), front-loading (e.g. early prototyping) to shift problem solving cycles to earlier phases of NPD (Bartezzaghi *et al*. 1997, Ruy and Alliprandini 2008), and the presence of a learning culture (Gieskes and Hyland 2003). Having continuous process improvement as an

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item on NPD team meetings' agendas ensures that the most recent activities are regularly reviewed (Caffyn and Grantham 2003).

When assessing these facilitators' effect on OL, existing studies' understanding of OL varies greatly. OL is perceived as an accumulation and subsequent re-use of experience within or between projects (Bartezzaghi *et al*. 1997, Gieskes and Hyland 2003); as the set of cognitive and behavioural processes that results from a group of people collectively creating and shaping new knowledge (Sawy *et al*. 2001); as individual or group inquisitiveness, challenging the status quo, experimenting, and learning from mistakes and positive outcomes (Caffyn and Grantham 2003); as the generation and transfer of tacit and explicit knowledge at the organisational level (Koners and Goffin 2005, 2007, Goffin and Koners 2008, Goffin *et al*. 2010); as the interplay between feedback processes and feed-forward planning, which are essential for a company to learn and thereby improve (Jayawarna and Pearson 2003); as a combination of two social learning theories, namely Nonaka's knowledge sharing and creation theory as well as Wenger's theory of communities of practice (Smeds *et al*. 2003); and as identifying and correcting errors based on an analysis of the process performance (Ruy and Alliprandini 2008). This variety of OL perceptions makes it hard to assess, compare, or integrate prior findings.

The OL 4I framework by Crossan *et al*. (1999) is comprehensive and widely recognised in the literature. However, extant studies on OL facilitators do not apply or refer to this framework. Instead, researchers focus selectively on various OL elements, rather than building upon and advancing a common framework to build on previous research. Such studies would encourage systematic and cumulative scholarship and, thus, help to assess fundamental research questions related to OL facilitators in NPD. Our study seeks to address this gap. We encourage greater coherence in future research by applying the 4I framework in the NPD area to enhance understanding of OL facilitators.

Value stream mapping (VSM) is a method introduced in the lean management literature that seeks to continuously adapt organisational processes. VSM is '[...] a method by which managers and engineers seek to increase the understanding of their company's [product] development efforts for the sake of improving such efforts' (McManus and Millard 2002: 1). The literature on VSM uniformly accentuates the visualisation and joint understanding of actual processes so as to improve them. This goal is based on a shared understanding and mutual adjustment of organisational members' activities (Seth and Gupta 2005, Seth *et al*. 2008) (see Table 1). However, VSM's causality as a facilitator of OL about NPD processes has not been researched to date. Our research helps to close this gap.

The paper is divided into the following sections: The next section provides the theoretical background to OL and VSM. This is followed by a description of our research methodology and data collection. We then present our case study results and discuss our findings. Finally, we highlight the implications of our findings for future academic research and offer practical suggestions for managers in the NPD field.

Theoretical background

Organisational learning about product development processes

'Organizational learning can be conceived of as a principal means of achieving the strategic renewal of an enterprise. [...] Renewal requires that organizations explore and learn new ways while concurrently exploiting what they have already learned' (Crossan *et al*. 1999: 522). In the NPD processes, learning and continuous improvement refer to organisational innovation capabilities' renewal or progressive enhancement (Bartezzaghi *et al*. 1997). Scholars have studied how organisations learn from different viewpoints, for example: single and double-loop learning (Argyris and Schön 1978); learning as processes of information or knowledge acquisition, distribution, interpretation, and storage (Huber 1991, Adams *et al*. 1998); and OL as the sum of an individual's learning, which is shared, developed, and refined in groups and finally becomes institutionalised (Dougherty 1992). A framework that embraces these major OL schools of thought is the 4I OL framework developed by Crossan *et al*. (1999). We apply this framework in our research (see Figure 1).

The 4I OL framework contains four processes (Crossan *et al*. 1999): *Intuiting* is a subconscious process of pattern recognition based on a highly sophisticated and complex map inherent in a personal experience stream. Intuiting enables the individual to perceive patterns in known and new situations, to know almost spontaneously what to do without conscious, deliberate, or explicit thought. During intuiting, the pattern and associated actions are familiar, but the underlying justification has receded from conscious memory. In addition, there is no language to describe the insight or explain the intended action. Consequently, while intuition may guide an individual's actions, he or she cannot share this intuition with others.

Table 1. Existing literature on VSM in the context of manufacturing.

Study	VSM objective	VSM approach	VSM key aspects emphasised
Abdulmalek and Rajgopal (2007)	• To identify and to take steps to eliminate all types of wastes • VSM creates a common basis for the process, thus facilitating more thoughtful decisions to improve the VSM	• Taking the VSM perspective means working on the big picture and not on individual processes	• Waste elimination • Systems perspective • Decision support
Browning *et al.* (2006), Browning and Ramasesh (2007)	• Continuously improving the NPD process as a model for project execution and its associated management	• While similar to traditional flowcharting in many respects, VSM emphasises activity attributes such as cycle time, duration, and value added	• Activity attributes/ factual data
Brunt (2000)	• Removing waste	• The benefit of removing waste will be most fully realised when we look at the big picture – the VSM – so that the whole – rather than individual processes – can be optimised	• Value orientation • Waste reduction • Systems perspective
Emiliani and Stec (2004)	• VSMs identify ways to get material and information to flow without interruption, they improve productivity and competitiveness, and help people to implement systems rather than isolated process improvements	• Not specified	• Uninterrupted information and material flow • Systems perspective
Grewal (2008)	• VSM enables seeing the entire process in its current and desired future state, and to develop the road-map • People often resort to a fire-fighting mode and lose sight of the overall system and their roles in it. VSM allow one to step back and consider the entire operation, from customers to suppliers	• VSM is the process of visually mapping the flow of information, as it is, and preparing a future state map • VSM is a visual illustration of the process, which helps us to visualise the cycle times, inventory at each stage (work in progress), and manpower • VSM is a tool to identify waste and improvement areas	• Visualisation of current state and desired future state • Systems perspective • Information flow • Customer orientation
Haque and James-Moore (2004)	• The VSM is a high-level description of a process used to perform analysis of the as-is state and to help develop the to-be state. It is a strategic decision-making tool in lean implementation	• VSM clearly shows the customers, suppliers, control functions, and the key phases of the process, together with key quantitative pieces of information that relate to the manufacturing process performance	• Visualisation and integration of all process participants • Quantifying process performance
Hines and Rich (1997)	• Waste identification and reduction	• VSM is a suite of tools to identify waste in individual value streams and to find an appropriate removal or reduction route	• Waste reduction
Hines *et al.* (1999)	• Internal process benchmarking, comparing the current value adding and wasteful activities with what the process might look like if a realistic percentage of the waste were removed	• VSM is a type of specific process benchmarking in which a particular process's initial performance is compared internally with how good that process could be	• Internal process benchmark (control measure)
Klotz *et al.* (2008)	• VSM is an intermediate step in process improvements	• VSM is based on the analysis of the process, development of an improved future state map, and its implementation	• Systematic process redesign
Lasa *et al.* (2008, 2009), Serrano and Ochoa (2008)	• The VSM tool supports system redesign • VSM is a suitable guide for the application of different lean techniques at a dock-to-dock level in companies	• VSM fulfils the utility requirements of a redesign technique: (1) analysis of initial situation is based on numerical data and a graphical interface, (2) provides a systemic vision, (3) provides a common language, and (4) provides the strategic plan's starting point	• Systematic process redesign • Decision support for docking of further lean techniques

(*continued*)

Table 1. (*Continued*).

Study	VSM objective	VSM approach	VSM key aspects emphasised
McManus and Millard (2002)	• The VSM of a process serves to describe a highly complex, real system in a less complex 2-D format. This simplification facilitates understanding and provides a common language	• VSM is simply the method by which the outcomes of value stream analysis are depicted or illustrated	• Simplified process visualisation
Oppenheim (2004)	• The VSM is a comprehensive method that allows for understanding of how a process really works and supports the project planning	• The VSM lists all the activities that create value. VSM combines a process map with data on how the process works (effort/cycle time)	• Visualisation of actual 'lived' process
Parry and Turner (2006)	• VSM enables people to see and communicate the process • Each person involved can see and understand the different aspects of the process and its status at any time	• When trying to understand, design, or manage processes, VSM is a core tool used by all lean practitioners	• Understanding and communicating process
Pavnaskar *et al.* (2003)	• VSM identifies and measures waste due to the incapability, inefficiency, and unreliability of information, time, money, space, people, machines, material, and tools	• VSM is based on a graphical tool used to map the as-is situation, to identify opportunities for waste elimination, and to decide on the improvements to be implemented	• Process visualisation • Waste reduction
Seth and Gupta (2005)	• VSM concepts are developed to understand the interdependence of one function, department, or even whole unit on another, and to get a holistic view of a situation • VSM links people, tools, metrics, and reporting requirements to achieve a lean enterprise. It provides clear and concise understanding about lean expectations. It allows everyone to continuously improve understanding of lean concepts	• VSM shows various important process details, such as cycle time, uptime, and time available. It also shows accumulated inventory at various stages. Furthermore, it describes the information flow. Most importantly, it summarises information about actual value adding time and total lead time. Different times and other factual findings' holistic visualisation triggers improvements	• Understanding interdependencies and information flow • Activity attributes/ factual data • Enables under-standing of lean concepts
Seth *et al.* (2008)	• VSM helps management, engineers, suppliers, and customers to recognise waste and its sources • VSM provides an image of the current state as well as a guide of the gap areas. They help one visualise how things would work if improvements were incorporated. They address gap areas, which leads to a road-map for improvement	• VSM differs from conventional recording approaches as it helps one visualise station cycle times, inventory buffers at intermediate stations, manpower deployment, uptime or resource utilisation, and the information flow in the given area • Taking a VSM perspective means working on the big picture and improving the whole, not just individual processes	• Waste reduction • Visualising future state • Identify gap areas
Snyder *et al.* (2005)	• Process improvement	• VSM is a standardised way of documenting a process and then applying a systematic method for analysis/improvement	• Standardised process documentation • Systematic analysis

Interpreting is the process during which an individual picks up on individual learning's conscious elements and shares it at the group level. In other words, this process moves from the pre-verbal to the verbal. Interpreting is a social activity that creates and refines language through conversation and dialogue. Images are clarified by sharing perceptions, pieces of data, startling observations, and cognitive maps in a group. Furthermore, shared meaning and understanding are created. Interpretive processes move beyond the individual, and become embedded within the workgroup, reducing ambiguity. Moreover, language not only helps the individual and group members to learn, but it preserves – for better or for worse – what has been learned.

Integrating is the process of developing a new and deeper shared understanding among individuals by means of continuing conversation in a group. This shared meaning can result in participants' spontaneous, mutual action adjustments once they agree on a course of coherent, collective action. Shared meaning also forms the basis of negotiated action, which often results in a behavioural change or development. By integrating individual interpretive processes, a shared understanding of what is possible is gained. Individuals interact with, and attempt to enact, this possibility.

Institutionalising is the process of embedding individual and group learning into the organisation's systems, structures, strategy, routines, prescribed practices, and investments in information systems and infrastructure. Tasks are defined, actions specified, and organisational mechanisms established to ensure that certain actions occur. At some point, the organisation's influential members reach a certain degree of consensus on or shared understanding of institutionalised practices. Once learning is institutionalised, it usually endures for a while. Furthermore, the 4I framework links learning at individual, group, and organisational levels. Accordingly, feed-forward learning progresses from individuals' intuiting processes, through group interpretation and integrating, to organisational institutionalisation. Conversely, in feedback learning, institutionalised mechanisms guide future individual or group learning (Crossan *et al.* 1999).

Value stream mapping

VSM's underlying assumption is: 'Whenever there is a product for a customer, there is a value stream. The challenge lies in seeing it' (Rother and Shook 1998: 102). This method focuses on the metaphor of organisational activities that add value (or not) to a final product and form a continuously flowing stream of (or non-)value-adding activities. VSM comprises (1) the current state map by visualising the process as it is being deployed, and (2) the future state map, which is a picture of the process after inefficiencies have been removed (Hines and Rich 1997, Brunt 2000, Haque and James-Moore 2004, Grewal 2008). Table 1 summarises existing research on VSM in the area of manufacturing. Literature along this line emphasises slightly different key aspects of the VSM approach. While some researchers describe VSM mainly as a method for visualising processes and supporting process redesign (Klotz *et al.* 2008), others see VSM more as a strategic element in supporting organisation-wide lean transformation (Seth and Gupta 2005, Grewal 2008). According to these authors, VSM helps to develop a road-map, improves overall understanding of lean methods, and enables better-informed decisions on how and when to embark on further lean techniques. We hold that it is only when VSM is used in accordance with the latter perspective that it can fully unfold its potential for individual and OL.

Mapping the current state or 'as-is' situation of an organisation's NPD process follows three steps (McManus and Millard 2002, McManus 2005, Locher 2008): Firstly, a typical development project – one that is representative of the firm – is chosen. Key participants are identified for this project and invited to a joint VSM workshop. Secondly, a wall of the meeting room is covered in paper for the VSM visualisation. The wall is then divided into different swim lanes (or columns), each capturing a department's activities or working packages concerning its contribution to the particular development project. This information is written on the paper (Figure 2).

Activities that have input or output relationships with other activities are then linked with lines. The participants thus visually map the flow of information and material. Lines that link activities across swim lanes clearly indicate the many functional interfaces that the information crosses as well as the material flows between the individual activities.

Although this process is in many respects similar to traditional flowcharting, VSM includes a third step – metrics and attributes are added to each activity. Examples of such metrics and attributes are the actual duration (lead time); the part of that time that was spent on value-adding work (process time); the resources used; the quality of information (completeness and accuracy); the inventory or work-in-progress; and control mechanisms (such as first in, first out) (Browning *et al.* 2006). VSM provides templates for capturing all the information, and uses clear symbols and a style that helps to depict the activities and the links between them.

After the current state of a particular development project has been recorded, the process is analysed to identify the waste and improvement areas. Each development activity is evaluated with regard to its value-adding contribution (Klotz *et al.* 2008). The customer perspective is crucial in evaluating the value that is added. Target conditions are formulated for each activity; they describe how the activity will be performed in future, how it is positioned in the information and material flows to other activities, and what is expected (i.e. what is hypothesised) of the activity's future performance (e.g. lead times or resources used) (Rother 2009). Furthermore, a future state map is drawn that depicts the NPD process of the firm and aims to achieve better NPD performance.

However, the existing literature is limited to statements and anecdotal evidence on VSM's importance and offers largely untested guidelines. None of the existing research has explicitly considered the OL literature. Our research seeks to help close this gap.

Research methodology and data collection

We applied comparative, longitudinal case study research, which gave us the opportunity to examine continuous processes in context (Pettigrew 1990). In our fieldwork, we collected and validated our data through triangulation by gathering different types of data, using them as cross-checks (i.e. interviews, observations, and cross-case analysis) (Eisenhardt 1989, Yin 1994). Further, all data were collected and analysed by at least two to four researchers so as to avoid perceptive or subjective interpretations of the data. The comparative case studies were conducted at four automotive suppliers in the German-speaking car supplier industry. As a mature industry, it offers a great opportunity for theory building (Eisenhardt 1989).

Firstly, we conducted multiple in-depth and semi-structured interviews, focusing on contextual data to structure, understand, and integrate each case (i.e. company details, project type, and details about the development department). We interviewed R&D department heads and process team members, as they have a key role in the change process under analysis. Secondly, data were collected by observation in two VSM workshops in each case company. *The first VSM workshop:* Each case started with a VSM drawing of a typical completed project's entire development process – from the customer's order to the production delivery – as an as-is state. Figure 2 displays a part of case company Y's process map with the VSM metrics captured. Each VSM workshop lasted 3 to 6 h. *The second VSM workshop:* Each case company undertook a second VSM. An as-is analysis was done of a selected sub-process with the employees involved. During the workshop, the participants also discussed and identified individual and system process problems in order to develop the as-is state into a to-be VSM.

Later, regular *improvement workshops* took place (e.g. monthly at company Y) in a dedicated room (called the obeya, which is Japanese for 'big room') in which process maps, problem lists, and measures were displayed on the walls. In these meetings, the participants defined the measures' progress and the responsibilities and outcomes for each measure, and reported progress based on VSM metrics such as lead and process time. At least two researchers attended these workshops for observational data collection. Immediately after the workshops, researchers cross-checked the collected data. Furthermore, semi-structured interviews were conducted, with an average of 15 workshop participants per case. The interviews lasted between 60 and 90 minutes and captured the how and why of changes (Yin 1994) (i.e. specific problems, root causes, continuous improvement measures, and further improvement areas).

Results

While in all cases, the implemented VSM methodology was strongly based on McManus' (2005) and Locher's (2008) approach, the realisation of VSM varied from case to case. While companies W and Z conducted

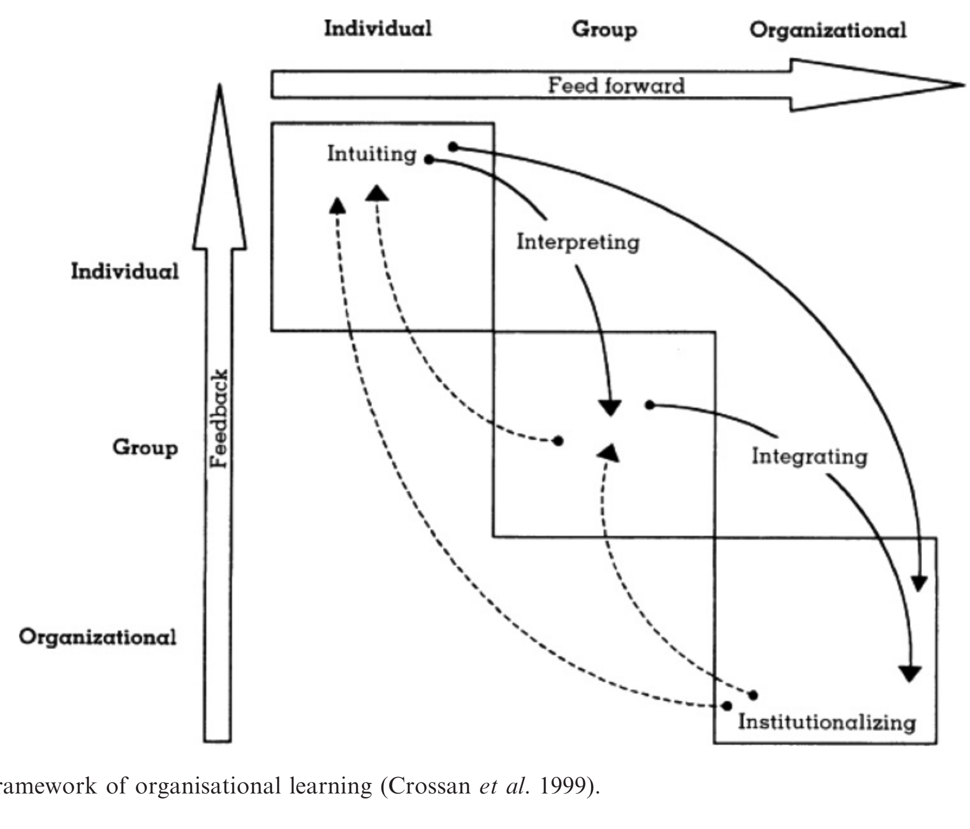

Figure 1. 4I framework of organisational learning (Crossan *et al.* 1999).

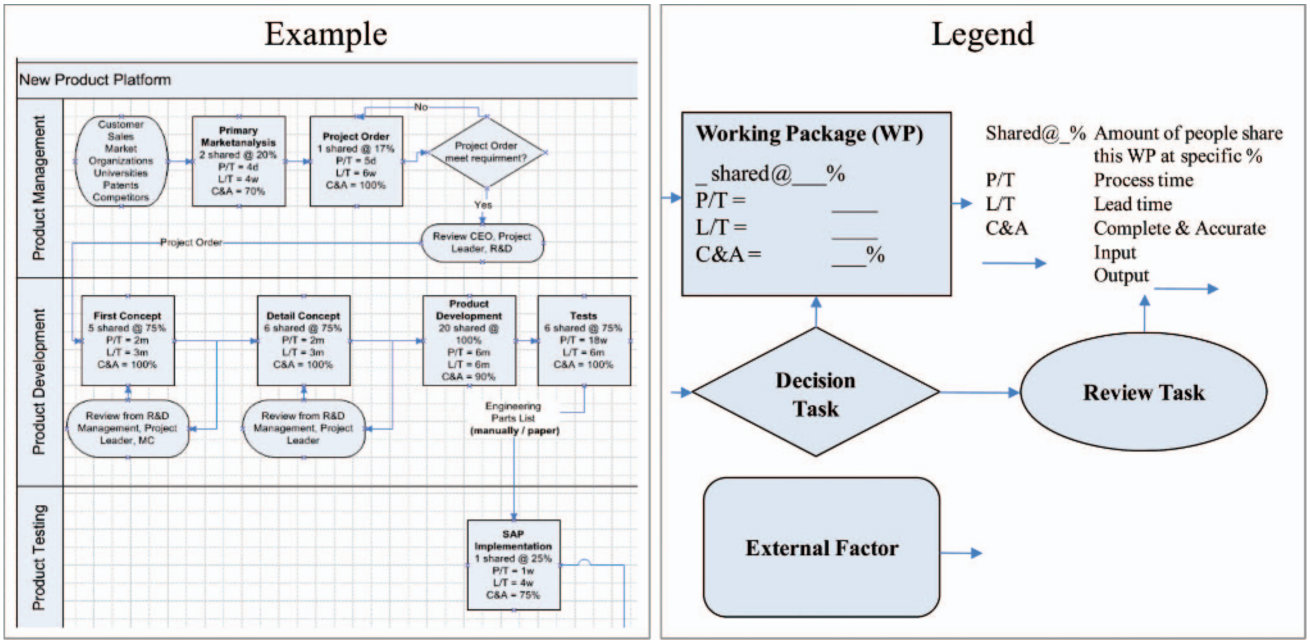

Figure 2. VSM map with legend adapted from metrics of Locher (2008) and McManus (2005).

their *first VSM workshop* with one experienced project manager, company X invited 12 engineers from a typical project, and each of company Y's departments undertook a separate VSM, all of which were then combined.

We then introduce our key findings. When presenting our qualitative research, we adopted the approach of alternating between 'telling' and 'showing' by weaving together the theoretical elements and live excerpts from our cases (Locke 2001). We summarised the data in line with the 4I processes of Crossan *et al.'s* (1999) framework.

Intuiting

Intuition may guide an individual's actions, but is difficult to share with others and observe. Before the firms undertook VSM, we therefore assessed the prospective participants' contextual background by means of interviews. In all four cases, there was a specific intuition about organising NPD projects and about their performance. In case company W, the project manager undertook all actions because this was company practice, while the other firms developed process maps to guide their actions. In case company Y, tasks were carried out more flexibly according to intrinsic knowledge, rather than by following a rigid process map. Before and during the first VSM, engineers in all case companies struggled to express their reasons for undertaking specific tasks. Subconsciously, they took their reasons for granted. According to Parry and Turner (2006), VSM enables people to understand and communicate the process and its performance by applying VSM metrics (e.g. lead time, process time, quality of activity output, number of people performing an activity and to what percentage of their time) (see Figure 2). The outline of the as-is process presented by VSM and its metrics also allowed participants to recognise the performance gaps, patterns, and problems' root causes. Individuals can reflect on and challenge their cognitive maps, which leads to richer intuiting processes and stimulating revisions of their prior understanding (Zietsma *et al.* 2002). In line with Zietsma *et al.* (2002), we conclude that OL is more adaptive when intuition is informed by the explicit consideration of facts and alternative viewpoints, which VSM and its metrics offers.

Interpreting

In all four cases, the engineers preferred the VSM methodology, with its clear symbolic language, metrics, and systematic procedure, over general project reviews that focus rather unsystematically on major project occurrences. In case company X and case company Y, representatives from the process management and quality department mentioned that they were astonished that such rich and valuable discussions were held in the VSM workshops. The usual finger-pointing was absent, and discussions focused on the factual data. Furthermore, they were amazed at the extent of the participation by the engineers, who are normally not easily motivated to implement improvement initiatives. Thus, we observed that VSM fostered '[. . .] dialogue [as] a discipline of collective thinking and inquiry, a process for transforming the quality of conversation' (Crossan *et al.* 1999: 529).

Prior to VSM's application, process improvement conversations referred to the general NPD process. As this is an abstraction from day-to-day practice, the conversations were rather removed from reality. By using a specific project as an example when undertaking the VSM and by capturing the according metrics, the collected data were given precise context and were factual. Individuals who were challenged by the group – 'Did you really work that long on this working package in project A?' – often subsequently adjusted their estimates. An engineer in case company X remarked that the company's existing process model was merely an idealised representation, while the VSM method provided a clear picture of what actually happened every day. In case company X, the head of quality electronics and one of his employees were present in the VSM workshop. While mapping their working packages, the supervisor described the quality of these activities. His subordinate, who was more involved in the day-to-day project operations, frequently contradicted him. He argued that what his superior drew was not what happened in practice. Reality often necessitated circumventing activities' quality standards. *Ambiguity was therefore reduced*, which is in line with the literature: '[. . .] equivocal situations are often resolved through a group interpretive process' (Crossan *et al.* 1999: 528)

Creating a shared understanding of actual work practices is part of the interpretation process. Abstractions that are detached from practice distort or obscure a practice's intricacies. Without a clear understanding of such intricacies and the roles they play, the practice itself cannot be well understood. Such understanding cannot be created (through training) or enhanced (through innovation) (Brown and Duguid 1991, Rother 2009), nor do manuals specify actual practices. Instead, understanding is captured and promulgated by particular data and by employees' stories, which reflect the practice's historical complexity (Crossan *et al.* 1999). Hence, metrics and storytelling are significant parts of the learning process (Davenport and Probst 2002, Abma 2003). VSM actively captures data and stories and visualises them as it maps the actual activity flow in a specific project, rather than in an abstracted, general process description. According to Seth and Gupta (2005), VSM differs from conventional recording or process modelling approaches, as it increases understanding of how a process really works. Because VSM stimulates reflection on and the sharing of observations in an NPD project with other engineers, *shared understanding* and *interpretation* emerge (Weick and Roberts 1993, Crossan *et al.* 1999).

A project manager in case company Y noted: 'It was a lightbulb moment to see certain things, especially how many process time hours were spent per project on detailed software development'. In case company Y, an engineer said that he had not known that his downstream production colleague could start on his work two weeks earlier if he received a rough estimate of the product proportions early on. Based on this insight, company Y later altered its process accordingly, shortening their lead time by approximately 20%. In case company X, an engineer questioned an activity's number of iterations and asked his colleague: 'Why do you have such a huge difference between the actual process time and the lead time?' In VSM terms, he sought insight into his colleague's work. '[. . .] once things are named, individuals can make more explicit connections among them' (Crossan *et al.* 1999: 528). During a development project, employees have limited perceptions of the project's activities and progress. With VSM, they can – in retrospect – observe how other team members saw the project, which reduces ambiguity. VSM *provided a shared language* for communication (McManus and Millard 2002) and allowed each member to observe and comment on the process (Smeds *et al.* 2003), to *share his or her understanding* with others. In doing so, organisational members reduce equivocality by interpreting through 'shared observations and discussion until a common grammar can be agreed upon' (Daft and Weick 1984: 291)

Owing to time and resource restrictions, case company Y decided to undertake VSM separately in each department, before combining the results. In each department, engineers mapped their activities, discussed lead and process times, and identified customer value from their perspective. When the departments' maps were combined, it became apparent that each department had developed a different (i.e. their own) definition of customer value. The departments accused one another of misunderstanding the term, and the discussion got out of hand. Approaching VSM in such a fragmented manner led to isolated perceptions and revealed that a shared understanding of the overall process was sorely needed.

In case companies W and Z, only one project manager and one or two process management team members attended the VSM workshop. While it was easier to define the terms, as only a few individuals were involved, less information was available for sharing. The discussions were fairly tiresome and the quality of the visualised process was significantly lower than in the other cases. While '[i]nterpreting [. . .]

creates and refines common language' (Crossan *et al.* 1999: 528), this did not happen in cases W and Z. Furthermore, in case companies W and Z, various departments had to rework the VSM after the workshop to correct and complement the process map and metrics. Overall, collective learning was much lower than in the other companies. VSM enables a holistic visualisation: 'Taking the value stream viewpoint means working on the big picture and not individual processes' (Abdulmalek and Rajgopal 2007: 225). Our case comparison revealed that the presence of each affected department's representatives allows a shared language to develop and facilitates shared understanding; while their absence undermines a common language and a shared understanding.

Integrating

In each case, the different perceptions of how and why activities were conducted needed to be mutually adjusted. The customer value perspective was particularly useful in aligning and adjusting the groups' understanding. In case company X, an engineer asked why the group had to test their product three times and how this contributed to customer value. He argued that, from the customer's perspective, this might not be necessary. After discussing this, the group agreed. This is in line with VSM's two primary requirements: '[...] to understand the interdependence of one function, department or even whole unit [on] another, and to capture a holistic view [of] a situation [...]' (Seth and Gupta 2005: 46). VSM enables an overview of a project, which all the involved persons should have. However, how a project developed is likely to be perceived differently by different people. The reasons for these different perceptions include interpretative aspects, such as 'interpretative barriers' or 'departmental thought worlds' (Dougherty 1992), or even different perceptions of project models (Engwall *et al.* 2005). All of these have been identified as major learning barriers (Gieskes and Hyland 2003). By mapping a single process, instead of mapping the perceptions of all the people involved, VSM avoids such barriers to learning.

In all the study cases, the data on VSM metrics could not be fully quantified for all the activities. Engineers often struggled to provide data, for example, about the use of resources or activities' duration. They wanted to check with their colleagues and provide these numbers later, thus keeping conversations going after the VSM workshop. Furthermore, they integrated a broader organisational circle into the discussions. Moving beyond the metrics captured by the VSM, a case company Y representative noted: 'The deviation in the plans and actual times will be interesting'. The map therefore provided a starting point for *further inquiry* and *continuing conversation*. Specifically, VSM facilitates a continuous conversation about process steps by having people with different perspectives in the room (McManus 2005). As Crossan *et al.* note: '[...] through the continuing conversation among members of the community [...] shared understanding [...] develops' (1999: 528).

In case companies W and Z, we observed less discussion and collective thinking between the – few – participants. Much of the crucial information was missing. Although some *new understanding resulted*, the effects were limited. Our observations are in line with Parry and Turner's (2006), who hold that VSM seeks to convey people's individual messages as well as their deeper, interconnected meanings. VSM enables capturing these messages' interrelationships more effectively than one-on-one meetings (i.e. bilateral dialogue) between, for example, a process management team member who maps the process and individual project members. In case company X, the workshop participants worked individually for 15 minutes to identify and describe five relevant and key working packages for each department, along with the VSM metrics. The manager and several employees from company X's quality department were present. They first worked individually, then pinned the individually drafted working packages onto paper. There was a significant difference between the manager's descriptions and the employees' descriptions. The manager had a much broader view of his employees' functions than they did. The employees, however, could specify details of their working packages better than the manager could. Discussions followed, which resulted in *new shared knowledge* of the process's specifics. As the VSM evolves through the mapping of its process steps and their interpretations, other VSM participants develop a richer understanding of the phenomenon, which creates new, integrated approaches to solving problems.

In the four case companies, VSM helped to identify problems that had not been as apparent before. This provided a better understanding of the direction that *future improvement* should follow. An engineer in case company X said that he now understood that '[...] many problems at the end [of a project] result from the initial planning'. This is in line with the literature: 'VSM enables a company to see the entire process in both its current and desired future state, and develop the road-map that prioritises the projects or tasks to bridge the gap between the current state and the future (lean) state' (Grewal 2008: 404). Furthermore, 'VSM creates a common basis for the [...] process, thus facilitating more thoughtful decisions to improve the value stream' (Abdulmalek and Rajgopal 2007: 225). By creating a common basis, VSM enables the development of a mutual understanding by integrating perspectives and prepares for action and change in behaviour. For example, workgroups '... use their common language and the conversational process to negotiate mutual adjustments to their actions' (Crossan *et al.* 1999: 531). Furthermore, 'Whereas the focus of interpreting is change in the individual's understanding [...], the focus of integrating is coherent, collective action' (Crossan *et al.* 1999: 528).

Institutionalising

In all the case studies, the VSM and the subsequent problem and waste analyses triggered organisational and individual behavioural change and development. Using the VSM methodology was an eye-opener, not only for the engineers involved, but also for managers. The companies' process management team and the teams driving the continuous improvement efforts mentioned that, before they used VSM, they struggled to explain themselves and their situation, especially to top management. Management seemed not to understand why it was so hard to achieve continuous improvement in the product development process. They suspected that the engineers were non-cooperative and resistant to change. Hence, in response, management advocated an increase in control. In company W, the CTO wanted to implement key performance indicators (KPIs) that would allow them to measure and track continuous improvement. At that time, the process team felt that implementing KPIs as a formal mechanism would be short-sighted and rash. A company W team member remarked: 'Performance metrics are certainly important, but deciding on the wrong metrics might frustrate people, and lead to local optimisation rather than a systems point of view, which would nurture continuous improvement. KPIs would be counterproductive. We cannot rush into this. We first need to understand the interfaces better and how people work together'. Hence, employees felt that their CTO needed to be patient and invest more time in analysis, but they could only argue from their gut feeling. Company W's VSM results strengthened their position. When the results were presented to management, it helped them to understand the engineering process's complexity. This insight led to a behavioural change. In all four companies, management became convinced that standard approaches and formal mechanisms such as KPIs, although important, might not be the right measures to initiate continuous improvement. Instead, having understood that organisational adaptation will first require *new structures, systems, and procedures* that stimulate active *involvement, interaction, and communication*, three of the four companies adopted a new approach, allocating a dedicated room (obeya) for the process. As case company X is spread over multiple locations, it pursued a virtual obeya concept. Hence, in Crossan *et al.*'s words, we observed that, 'Generally, that which becomes institutionalised in organizations has received, at some point, a certain degree of *consensus or shared understanding among the influential members of the organization*' (1999: 530).

Regular improvement workshops were held in the companies' obeyas, where various process maps, problem lists, and measures had been placed on the walls. Company Y even converted its main meeting room – which has glass-walls and is located in the middle of their engineering floor – into its obeya. In three companies (Y, W, and Z), this room, with the VSMs as a focal element, became the hub of continuous improvement efforts. During regular workshops, problems identified through the VSMs were discussed, tasks were defined, actions specified, and organisational mechanisms were put in place to *ensure that routinised actions occurred, such as monthly improvement meetings in companies W and Y*. Learning became '[...] embedded in the systems, structures, strategy, routines, prescribed practices of the organization, and investments in information systems and infrastructure' (Crossan *et al.* 1999: 529)

In case Z, the process management department's representative stated that the physical structure (room) had two main advantages. First, for most engineers, a learning organisation is what Okhuysen and Eisenhardt (2002) call 'a second agenda issue'. Their primary task is to solve engineering problems and ultimately develop an automotive part or component. Thinking about this process and its improvement requires group members to pay attention to this second agenda. The obeya, with its VSMs, allows the participants to switch quickly between product-oriented thinking and process thinking. Secondly, process management, seeking to extend continuous improvement to new sub-processes or new projects, found that the VSMs and obeyas facilitated the initial communication of this message. Engineers became involved in the idea of continuous improvement for the first time. However, VSM also *ensures coherent action*. The VSM concept helps one to visualise how things would work if certain improvements were incorporated. Addressing performance gaps in the existing state provides a road-map and performance metrics for improvements (Seth and Gupta 2005). Hence, VSM acts as a strategic decision-making tool for lean product development implementation, enabling tasks to be prioritised, and effectively bridging the gap between the current and the future (i.e. lean) state (Haque and James-Moore 2004, Grewal 2008).

If the plan produces favourable outcomes, the actions that are consistent with the plan become routines. VSMs are therefore used as a form of 'diagnostic' systems and 'interactive' systems (Simons 1991, 1994). *Diagnostic* systems are needed to ensure that the routines continue to be carried out and that the organisation produces and performs. An organisation uses these diagnostic systems to regulate the business's day-to-day routines to exploit the current understanding of the business. Simons (1991, 1994) also identifies another type of formal system, which he calls 'interactive'. Organisations use *interactive* systems to envisage how the future can or may differ from the past. This is facilitated when, according to Emiliani and Stec (2004: 643), 'current- and future-state value-stream maps are simple, high-impact, one-page illustrations whose significance relative to business performance can be easily grasped by senior managers'.

In all companies, the VSM analysis resulted in specific measures to improve interactions and working practices that had been characterised by inefficiencies. Upon conducting a second VSM workshop and analysing a prototype's sub-process in the presence of 10 people who contribute to this process, case company W found that the completeness and accurateness of information transferred about the interface between prototype building and quality inspections was far below 100%. Formal coordination mechanisms such as testing plans were inaccurate and little communication took place. As a result, the quality assurance employees had little foresight on when to test what, and were therefore reactive. After the VSM analysis had revealed this, a new way of interacting was established. The person in charge of quality started talking to three prototype manufacturing supervisors every Monday for five to ten minutes each, asking what they planned for the current week. We observed, here too, that '[...] individuals begin to fall into patterns of interaction and communication' (Crossan *et al.* 1999: 529). The information gleaned by the quality manager allowed him to better plan his work, by commencing customer specific set-ups in advance. This improvement resulted in an overall and sustainable decrease in prototyping lead time of 4 to 5 h.

Furthermore, in later visits to the companies, we found they had not only implemented the VSM-based improvements, but had also tailored the VSM approach to their specific needs – a clear indication of institutionalising OL. Even participants initially reluctant to use the VSM approach realised that 'VSM might not be perfect but it is the best we have', and used it for improvement workshops.

Discussion and implications

We investigated how VSM facilitates OL on NPD processes. We used Crossan *et al.*'s (1999) framework as a reference for OL. The results of our comparative case study analysis revealed that VSM does facilitate OL in the context of NPD processes. In particular, intuiting (consciousness of behaviour), interpreting (sharing of understanding), integrating (change of understanding), and institutionalising (behavioural change) are sustainably enhanced. Hence, our data suggest that VSM is effective as a facilitator for feed-forward learning, when intuitions and interpretations are shared and integrated as they are articulated tangibly in a form and language that others can access and understand (Crossan *et al.* 1999).

Our observations indicate that the VSM approach's effectiveness also derives from the highlighting of activity attributes such as process and lead time, and quality of input and output. By using factual data, the method offers stronger support for the sense-making of the subjectivity of collective/group actions. This is important for interpretation and integration. Other approaches to glean group knowledge (e.g. post-project audits or the discussion of Gantt charts) are not as effective as VSM in facilitating OL, even though they illustrate process steps, interdependencies, and process time. In contrast, the terms of VSM, the focus on eliminating non-value-adding activities, the consideration of loops or metrics characterise VSM a method that addresses tacit knowledge and generates a common frame among the participants, while also going beyond this. According to Crossan *et al.* (1999), what has been learned feeds back from the organisation, to the group and individual levels. This learning affects intuition, i.e. how people think and act. While we hold that VSM might also facilitate feedback learning, we were not able to sufficiently verify this. Because such learning processes occur over longer periods, such changes might be observable in our case companies in future.

Furthermore, our comparative analysis revealed that VSM's effectiveness as a facilitator differed across the cases. In cases X and Y, representatives from the departments that contributed to NPD attended the VSM workshops. In these companies, OL was enhanced. Case company W saved approximately 4–5 h for each new prototype they build and company Y shortened their lead time for ordering prototype material for approximately 20%. Being faster is beneficial to these companies, as it leads to a competitive advantage, less engineering hours, and lower costs. As product development is an ongoing endeavour for both companies, they benefit ongoingly. Thus, OL expresses itself in a sustainable benefit, which repeats itself with every new project. This was visible to the researchers who have conducted several follow-up visits approximately every two months. Therefore, taking a medium-term or even a long-term perspective, the benefits gained did justify the efforts undertaken and the investments made by these case companies through having 12 engineers occupied in a one-day workshop. In cases W (first VSM) and Z, only two or three participants attended, and little OL took place. We therefore derive that merely applying VSM without considering *how* it is applied is insufficient. VSM only supports OL on NPD processes if representatives of the different NPD functions are present. Overall, both successful and less successful cases improved our understanding of the subject matter, given that less successful examples are seldom described in the literature. Our findings align with those of previous studies that emphasise broad participation in order to gain shared understanding (Weick and Roberts 1993, Parry and Turner 2006) as well as stronger acceptance of the common basis (Abdulmalek and Rajgopal 2007).

Theoretical implications

Empirical research on VSM has mainly been conducted in the manufacturing context (e.g. Hines *et al.* 1999, Darlington and Rahimifard 2006, Agyapong-Kodua *et al.* 2009, Anand and Kodali 2009, Lu *et al.* 2011). In our work, we support and strengthen studies on VSM in the area of NPD (McManus and Millard 2002, Oppenheim 2004), which differs significantly from VSM in manufacturing. More functions are involved, resulting in a higher variance in the interpretations, and therefore greater ambiguity. Because the activities, as well as the value and waste created, are less physical and more intangible (knowledge and information), VSM requires the participants to provide a higher degree of abstraction. Finally, a behavioural change (improvements) is often based on engineers' improved collaboration, rather than on the (p)re-programming of their work.

The literature on VSM emphasises the customer's importance in assessing how much value activities add (Browning 2003). However, research has to date neglected the focal firm's position in the supply chain. While firms at the end of the chain supply consumers or end users, suppliers must provide value for their customers (next in the chain) as well as for end users. This is challenging in terms of creating value, but also for specifying customer value. Our empirical research contributes to the literature; specifically, it enhances the literature on lean product development and provides insight into VSM's applicability for suppliers. However, more research is needed to understand customer value as a multi-dimensional concept.

The literature reports on research in which the OL 4I framework has been tested as an antecedent for business performance (Bontis *et al.* 2002) and for developing technological distinctive competencies (Real *et al.* 2006). Case studies apply the framework to research radical organisational change (Zietsma *et al.* 2002, Crossan and Berdrow 2003) and to research total quality management (TQM) practices (Ferguson-Amores *et al.* 2005). Only Stevens has studied development activities (i.e. new service development) through the OL lens of the 4I framework (Stevens and Dimitriadis 2004). Our research contributes to this literature stream by applying the framework to better understand OL in NPD.

Managerial implications

VSM's validation as a facilitator of OL offers managers new perspectives. By enhancing OL's occurrence in NPD, as described above, managers in charge of NPD can improve the development process' efficiency. For instance, our findings suggest that management must provide the necessary resources, such as ensuring that engineers attend VSM workshops. Managers will then gain a better understanding of actual R&D processes. Since VSM provides fact-based reference values of, for example, the efficiency of timing, resource allocation, and inter-departmental collaboration, it can help managers with decision-making in current and future projects. Furthermore, mapping might reveal a significant discrepancy between the actual process and a company's currently documented product development process model. In this case, managers must decide whether reality should follow the procedural instructions, or if the current standards should be adjusted. VSM can further support decisions regarding where more discipline, or flexibility and process standards' customisation, might be the right courses of action. Concerning training, VSM can be used to provide new employees with an easy-to-follow overview of processes. VSM also facilitates new employees' understanding of the activities undertaken by project members from other departments, and of the connections between departments. Finally, our work confirms the 4I framework's premise that the four learning processes link the individual, the group, and the organisational levels. Managers must consider OL's multilevel nature when taking steps to enhance adaptation and continuous improvement in the organisation.

Limitations and further research

This study has limitations. Our findings should be considered as exploratory and need confirmation in a larger context beyond supplier companies in the German-speaking automotive industry. Furthermore, we worked with a fairly small company sample. A similar study can be done with a much larger sample, using a quantitative approach. However, our case study indicates that engineering data's development can be visualised to enhance project management and to identify NPD process improvement opportunities. However, many questions still remain unanswered. For example: How can VSM be harnessed to support self-organisation in development projects? How can companies incorporate engineering data quality development into various measures? How can companies understand customer value better as a means of orientation and of constantly adjusting and aligning internal engineering work with customer demands?

With reference to the 4I framework, future research could investigate previously researched facilitators such as post-project learning or milestone reviews and their effects on OL so as to compare their effectiveness. Additionally, other methods – such as Six Sigma or Carnegie Mellon's CMMI (Capability Maturity Model Integration) model – implicitly undertake to support NPD processes' continuous improvement. However, these relationships have not been explicitly researched. The question arises as to whether there are differences in how these methods affect OL and its sub-processes. Possible research questions include: Which methods are more effective in facilitating (parts of) OL in NPD processes, and under which conditions? Future research could investigate these differences by using OL's 4I framework as a reference model to measure and compare these methods' facilitating effects. Our research sought to contribute to such systematic and cumulative scholarship.

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