Defining an Intellectual Capital Based Measurement Framework for Dynamic Distributed Software Development

Mikko Ruohonen1, Pekka Kamaja2, Timo Ingalsuo1, Katriina Löytty1
1 CIRCMI, School of Information Sciences, University of Tampere, Tampere, Finland
2 Haaga-Helia University of Applied Sciences, Helsinki, Finland
mikko.j.ruohonen@uta.fi
pekka.kamaja@haaga-helia.fi
timo.ingalsuo@uta.fi
katriina.loytty@uta.fi

Abstract: The paper presents the ongoing defining of a measurement framework with an intellectual capital (IC) perspective for dynamic distributed software development (DDSD). The topic examines building the capabilities, evaluating the efficiency and scaling up the performance of globally distributed software development teams in environments that demand high operational excellence and innovation performance.

The University of Tampere, Haaga-Helia University of Applied Sciences and the University of Helsinki are collaborating on a research project, DD-SCALE (2014-2016), with four industrial software companies working at the forefront of their industry. The objectives of the project are to investigate and develop measurement solutions, tools and work practices for managing and evaluating DDSD work. The project addresses the challenge of harnessing human and social capital assets for scaling high-performing teams to fit with high-performing organizations.

The research questions of the paper are: 1) What are the applicable dimensions, in the context of IC, of a comprehensive and scalable measurement framework for DDSD? 2) What are the relevant indicators for measuring the performance of DDSD? 3) How can a framework, its dimensions and indicators be effectively implemented in practice?

The chosen research approach is design and action research that has a qualitative emphasis. The theory perspectives of IC, performance management and distributed software development are applied. First, literature reviews were conducted. Next, data was collected from the participating companies by the means of interviews and workshops. The collected data was then analyzed by conducting a qualitative content analysis. The findings were then utilized for constructing the dimensions of the framework, identifying the measurement indicators, and designing prototypes for the implementation of the framework.

Thus far, the results include: 1) the human, structural and relational capital dimensions of the measurement framework that can be combined for examining companies on individual, team and organizational levels; 2) a categorized set of candidates for indicators; and 3) an outline of the construction as well as preliminary prototypes for implementing the framework.

The next steps of the research will include the advancement of the construction of the framework and prototypes. Examples of applicable deliverables derived from the construction will include a mobile barometer tool and an impact analysis solution for assessing DDSD work. The results will contribute to the management and development of work practices and help to realize the implementation of high performing software research and development (RD) operations within a dynamically and globally distributed setting.

Keywords: dynamic distributed software development, distributed teams, evaluation metrics, intellectual capital, performance management, software measurement

1. Introduction

In a networked business environment it has turned to be inevitable to make relation-based business operations. However, the management of such networks is challenging due to many forms of outsourcing, in which not only the information technology (such as servers in clouds) but also business and knowledge processes are being distributed through the whole network. Nevertheless, the networked business environment has evolved tremendously during the last two decades and now provides business opportunities for many knowledge-intensive companies (Lacity, Willcocks and Cullen, 2008). Consequently, many new and still emerging company forms have been created and, in particular, the offshore outsourcing of software development (SD) that took off in the US and Western European countries in the late 1990s has now led to

India, China and many other countries in Asia, Latin America or even Africa being identified as potential cost competitive countries or areas (CCC's) (Ruohonen, Mäkipää and Kamaja, 2014).

Unfortunately, if outsourcing is considered only a one-way operation that hands over assets, people, activities and knowledge to third-party management, it does not remain competitive. However, two-way, collaborative and network-based contracting that constantly evolves can release a company's knowledge potential and simultaneously release the provider's potential, resulting in mutual gain (Oshri, Kotlarsky and Willcocks, 2007). CCCs currently dominate due to their cheaper labour costs. However, human capital, human resource management (HRM) complexities and various administrative issues can result in unfavourable events. In particular, service levels, dynamic competencies and community-based activities can act as game changers when evaluating total costs.

The key rationale behind our DD-SCALE research, development and innovation (RDI) program is that the distribution of the RDI operations of SD companies is being challenged by the complexity of the combination of onsite, onshore, nearshore and offshore settings (Oshri, Kotlarsky and Willcocks, 2007). The research process is iterative in nature, and contains the three main perspectives involved in creating a new theory (Figure 1).

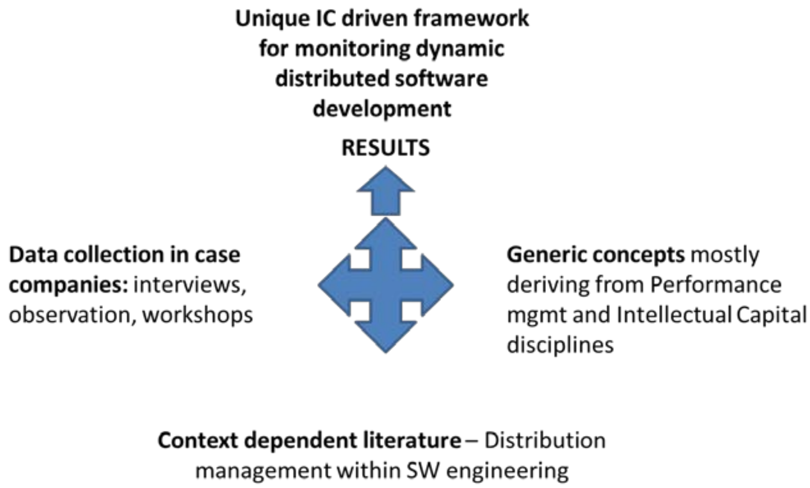

Figure 1: Research setting

DD-SCALE is a co-creation research program that runs from 2014 to 2016. The programme combines the knowledge and ability of three academic institutes, four SD companies and TEKES, Finland's leading technology and innovation funding agency, in their desire to improve the performance of global SD work. The program will also assist in formatting industrial policy settings to improve the Finnish ICT sector's understanding of the changing sourcing environment of SD companies, detect their competencies in executing this work in different work settings and enable dynamic sourcing through multiple sites.

2. Case company involvement

The four Finnish-origin case companies are world leaders that have globally distributed high-performing software teams in Asia and Europe. The characteristics and setting of these case companies are summarized in Table 1.

Currently, these companies are looking for even more business growth in the new markets created by the increase in the digitalization of work throughout the world. This means they must dynamically scale up their operational excellence and innovative performance in new distributed settings in order to attain sustainable and competitive advantage.

The findings of the field studies on the case companies suggest that the main driver of a company's search for enhanced analytics for the management of their RDI operations is the straightforward need to judge the overall productivity of a particular RDI site. The weakness of the current evaluation methods is that they overemphasize the salary levels of personnel and fail to consider other factors in a comprehensive way.

Table 1: A summary of the case companies

Case	Industry	Setting	The case company's main interest in DD-SCALE
A	Power and automation technologies	An internal software engineering department in a global company that has more than 150 000 employees	- the overall effectiveness of the innovation system to facilitate further business growth in high growth global markets, i.e. accelerating the idea-to-market deployment speed in an end-to-end process
C	Telecom	An international software, IT solutions and service provider, employing approximately 700 people	- improving the capabilities used for efficiency monitoring practices - solutions for the improved monitoring of site specific efficiency figures in order to increase the ability to manage the distribution of global RDI resources - the further development of tools and fact-based information for improving the monitoring and management productivity of teams
N	Maritime	A software solutions provider for ship design and operations employing approximately 175 people in eight countries	- more accurate and reliable performance reporting from different RDI sites and teams to determine the most efficient form of the organization and distribution of work. This research was conducted during the collaboration and performance of software engineering teams working within multisite software organizations
S	Telecom	A large telecom network and software company with approximately 20 000 employees; has a network of software development resources in a combination of on-shoring, off-shoring and near-shoring settings	- monitoring the less visible, more intangible and intellectual factors, especially those residing outside the current system efficacy of performance analytics, or even the company's borders - improved decision-making methodology for the management of new sites distributed around the globe; the current methodology would benefit from findings in improving software work performance metrics

With regard to the typologies of the distribution of RDI operations, at least two differing models are found. The first model is based on a bipolar setting where new software products are developed through work that is collaborative but performed at two remote locations. The second one is a networked model in which the resources of the RDI departments are spread over multiple locations and coordinated from a company's headquarters. Here the off- and near-shoring modes are dominant. Hence, a more precise formulation of the research questions would be to ask:

- How can the impacts of on-, near- and offshoring be measured?
- What are the appropriate indicators for monitoring a company's software development (SD) units and sites when they are spread over multiple locations?

Those two questions are additions to the original research questions but are mainly related to the third research question: How can a framework, its dimensions and indicators be effectively implemented in practice? The first additional question is particularly concerned with how to monitor the impacts of on-, near- and offshoring, which is a constant issue in the discussion of practical deliverables.

In summary, a common issue for all case companies is the need for an overall measurement framework that assesses the very roots of RDI organizations, while simultaneously meeting the global perspective involved in managing multiple RDI sites.

3. Context dependent theoretical consideration

A crucial issue in building a new measurement framework is the overall process from data collection through the interim concepts towards the actual artefact. Bourne et al (2000) and Franco-Santos and Bourne (2005) have discussed the design and implementation of performance management systems. They argue that the essential step in the early stages of that process, after establishing the research database, is capturing and conceptualizing the interesting phenomena that are the candidates for the actual factors of the framework.

The landscape for discovering new tools for managing Dynamic Distributed Software Development (DDSD) (see Ruohonen, Mäkipää and Kamaja, 2014; Kamaja, Ruohonen and Ingalsuo, 2015) is framed by the search for desired benefits, such as savings in cost and delivery time, securing IT manpower and achieving market proximity (see Dutta and Roy, 2005). This also applies to secondary objectives, such as inducing innovativeness (Kojima and Kojima, 2007). The counterforces acting against the benefits of the distributed management models are poor communication, such as gaps or unclear chains of command; cultural differences; the transferring of the business domain; decreases in project visibility; configuration management; a disconnect between project estimates and feasible results; client business security; document maintenance and synchronization (Hameed and Nisar, 2004). The ideal solution for the purposes of DDSD would be to provide a broad and deep analysis approach. The breadth of the analytical framework is due to the aforementioned challenges, but especially to the main categories and the factors that are present on the level of distributed teams (see Kamaja, Ruohonen and Ingalsuo, 2015; Löytty and Ingalsuo, 2015):

1) cross-cultural factors (Fontaine, 2007, Hudson, 2007);
2) organizational values and leadership (Schein, 2010);
3) communication in and between teams (Sahar, Raza and Nasir, 2013);
4) remote collaboration patterns between teams (Herbsleb and Mockus, 2003) and
5) knowledge management (Oshri, Kotlarsky and Willcocks, 2007).

The first main category, the cross-cultural perspective can be seen in two ways: 1) in the working of the multisite organization, and 2) in the working of multicultural project teams. Multicultural teams have a higher potential for greater success than single-culture teams do, but they also have a higher risk of failure. Cultural differences in project management can be difficult to navigate, especially in the software industry. (Hudson, 2007). It is important to acknowledge the importance of cultural competence. A good starting point for increasing cultural competence is offered by different cultural typologies. The advantage of these models lies in their power to make sense of a different culture, even if the person using these models does not have first-hand experience of the specific culture. The thorough consideration of the next main dimension, organizational values and leadership would require a more precise investigation of the underlying factors. House et al (2004) have presented nine dimensions of leadership which are in line with the five factors presented by Hofstede (2001). Other relevant taxonomies explain the cultural aspects involved in leadership (Trompenaars and Hampden-Turner, 1998) and the cross-cultural aspects of managerial work (Jacob, 2005).

Remote collaboration patterns are taken into use when managing the knowledge and the division of work between different sourcing sites. When the division of work is based on expertise, it utilizes the knowledge and expertise of a company's employees regardless of their geographical location, thus allowing these companies to access the pool of expertise available in offshore locations. Lastly, an expertise-based division of work approach requires that remote engineers and managers interact, and consult with their counterparts in order to solve design issues. Kotlarsky et al (2007) observed that companies which attempted to reuse components across different projects and products, and improve product flexibility through the application of component-based development were especially dependent on the success of a) inter-site coordination; b) knowledge management and; c) communication channels. Customer orientation and business models also have an influence (Oshri, Kotlarsky and Willcocks, 2007). In addition, Herbsleb and Moitra (2001) argue that cultural communication and knowledge management issues are also significant factors.

A quite recent set of categories developed by Prikladnicki and Audy (2012) that focus on the DDSD field are probably best able to link the IC tradition. The categories are distance, levels of dispersion, organizational structure, the practices of operations, culture, trust, collaboration patterns, the division of project work across sites, development methods, policies and standards, the measurement of the productivity of distributed software development and project management and leadership. Klein (2008, p.2) suggests this organizational culture and leadership is capital, whereas Bontis (1999, p.450) sees them as external to the drivers of intellectual capital. Linking intellectual capital to globally distributed software engineering is troublesome, not only due to the inconsistencies in the categories and their concepts, but also because of the differences between the objects of investigation. The distributed software design is anchored in the phenomena of the global software engineering context, whereas intellectual capital is interested in intangible assets. These categories and the related factors that emphasise the essence of distribution management are here considered as the lenses for ascertaining the ontologies residing in the area of interest (Kamaja, Ruohonen and Ingalsuo, 2015; Ruohonen, Mäkipää and Kamaja, 2014).

To summarize the theoretical discussion so far, it is evident that the literature discusses the categories and factors present in DDSD work in different ways and with a variety of perspectives and emphases. In an attempt to gain a unified view of the different factors that impact on the collaboration and productivity of distributed teams, the first steps taken in the DD-SCALE program were to create a multi-layered concept map based on a literature review (Löytty and Ingalsuo, 2015). The key findings were that distributed team collaboration and productivity are surrounded by various elements originating from different levels in relation to the team. The temporal, physical and socio-cultural distances often inherent in distributed teamwork have an important influence on the factors at the team, organizational and operating environment levels. These factors come closer to the core of doing the actual work. If successfully managed, the factors can support the collaboration and productivity of the teams, but if lacking or misdirected, they can effectively act as hindrances (Ibid 2015).

4. Research and Results

The contribution of this paper is to highlight the most current results of this research project in-progress. The further elaboration of the DD-SCALE project will be to move from the search for answers to the first research question, What are the applicable dimensions, in the context of IC, of a comprehensive and scalable measurement framework for DDSD?, to the second: What are the relevant indicators for measuring the performance of DDSD? In order to do that, the research agenda has been reshaped slightly to involve not only the performance metrics, but also the productivity perspective. Accordingly, RQ 2 is targeted toward explaining the performance and productivity of distributed software design work. This twofold setting can be explained by the need to separate the lagging and leading indicators from each other where the productivity measures are the lagging indicators and the performance indicators are the leading indicators. Parmenter (2007) explains that the instruments for measuring productivity refer to key result indicators (KRIs) like customer satisfaction or production efficiency, whereas the deeper rooted indicators beneath the KRIs are the performance indicators, PIs.

A set of semi-structured interviews and workshops were conducted in the case companies in order to establish the dimensions and candidates for the factors in the measurement framework. The transcribed interview material was analyzed by content analysis that aims to identify and conceptualize the relevant phenomena for measuring productivity in DDSD work. As a result of the analysis, 550 raw indicators were established. The elaboration work focused on examining the raw indicators in terms of generalizing and classifying the indicators and removing the duplicates and less obvious indicators.

The main categories and their subclasses were assessed as they were identified. Finally, a decomposition of the indicators, illustrating the productivity of distributed software engineering work divided into 17 categories and associated with 40 subclasses holding 320 indicators, was created (see Table 2). The presentation is depicted down to the subclass level. Besides this flat, one dimensional view, the columns of Table 2 refer to the cornerstones of the development work of the actual DDSD monitoring framework. These three fundamental perspectives are: (i) the Intellectual capital dimension in the first two columns; (ii) the DDSD work-related categories in the third column and, (iii) productivity in the fourth column.

Setting up these three major building blocks required research which was done according to the principles of grounded theory. In practice, the research identified the ultimate elements of productivity at the grassroots level, i.e. the indicators. The categorizations that were available on intellectual capital theory (Cricelli, Crego, Grimaldi 2014; Huang, Luther, Tayles 2007) were used to assist in the mapping of appropriate categories for the indicators. The rationale behind this was to gain a comprehensive and in-depth analysis of the causes underneath the tangible level of exercising the daily software engineering work. Instead of just meeting the level of performance indicators (Parmenter 2007), this journey went deeper into assessing the level of the capabilities and individual abilities that can be found regarding the presentations of the top-down fragmentations of intellectual capital. Eventually a rich and encompassing classification of the indicators, explaining the productivity present in the fragments of daily work in software companies was created.

An example of the structure of the decomposition is taken from the main category of *Team interfaces and collaboration* that comprises the subclass *Inter-team bonding* and which, furthermore, holds four indicators, one of them being *Established cross team connections for quickly accessing expertise (help).* Undoubtedly getting help outside the team is crucial for the team in question to continue their work in a troublesome situation and, moreover, avoid a stoppage that could negatively influence one of the main productivity measures, namely velocity. Similarly, each of the 320 indicators on the third level in the decomposition of the measurement framework have a direct, less direct or an indirect impact on productivity measures.

Basically, the four case companies use only two productivity measures: firstly, the net efficiency ratio, reflecting the quality level of the R&D operations, i.e. software engineering; and secondly, velocity which describes how quickly the new features are produced and delivered to the customers. In addition, the research brought forth a third one, the appropriateness of the product for the customer which was added to the model. In practice this necessitates that the vendor company frequently revises their product plans so that they aligned with the changing market demands. In other words, appropriateness for the customer is the downstream dependency of the vendor company. This measure has a strong effect on the collected research data, although it was not considered in the case companies' KPIs.

In contrast to downstream dependency, the vendor company is dependent on the technology it uses to fulfil its daily operations. The frequency of change in technology is slower than the changing demands of the market. Consequently, upstream dependency, which is potentially a fourth candidate for measuring productivity, was not as clearly identifiable in the research data. Mostly it was seen in terms of the changing technology of the development tools. For example, HTML 5 has replaced prior technologies for programming software code.

In summary, in addition to the two productivity measures: velocity and quality, two more were added: appropriateness for the customer and technological dependency, although the latter is still being determined.

Finally, weaving productivity together with the decomposition of intellectual assets in order to ascertain capabilities and abilities is a complex task. The aforementioned example of the indicator *Established cross team connections for quickly accessing expertise* has a direct impact on velocity and it is an obvious one for explaining the relationship between productivity and indicators. On the other hand, samples taken from *Management processes, practices and systems* disclose the complexity of defining the cross-reference between these two sides. Moving on from there, the indicator, *Avoidance of featurism in the design phase,* which is present in the subclass of *Processes, systems and practices,* suggests a disciplined practice for ensuring the scope of the design is protected against uncontrolled requests that can harmfully inflate a design with unnecessary features. From a productivity perspective, this particular indicator appears to be somewhat general as it affects the parameters of velocity, quality and appropriateness for customers.

The two examples here illustrate a way of connecting intellectual assets with measurements of productivity, which is highly burdensome and complex. In order to avoid blurring them with the complexity of analysing the value streams of the individual indicators (from the essence of the indicator up to the level of productivity, i.e. result indicators) was to apply approximations. The first approximation was to stay on the subclass level, i.e. not analysing individual indicators thus making sure that exceptions were accepted. This can be justified by pointing out that indicators belonging to the same subclass were similar in terms of how they impact on productivity. Hence the first approximation was acceptable. The second approximation was to select the most obvious productivity measures and to disregard the less obvious in linking the indicators. In the second approximation, the theoretical number of permutations for linking performance parameters with indicators was reduced from approximately 1000 (320 x 3 (4)) down to 60 permutations (40 subclasses x 1 to 2 parameters). The full view of the correspondence between the subclasses and the productivity measures is not shown in Table 2. The fourth column provides only an indication of the appropriate productivity measures.

Table 2: A unified view of the categories and the associated subclasses affecting overall productivity in software engineering work

IC-orien-tation	Main category – IC orientation	Subclass explaining DDSD work	Productivity – emphasis on
Human	1. Job Skills	1. Basic job skills 2. Problem solving skills 3. Enhanced job skills	Velocity, Quality a core category
Human	2. Knowledge	4. Fundamental knowledge 5. Wide-spectrum knowledge 6. Domain knowledge	Velocity, Quality, Appropriateness - a core category
Human	3. Social abilities	7. Belonging 8. Social intelligence 9. Communication 10. Organizational flexibility	Supports categories 1 and 2
Human	4. Motivation and engagement	11. Satisfaction and commitment 12. Obedience to rules. being flexible regarding rule breaking/bending 13. Ownership	Supports categories 1 and 2
Human	5. Renewal and learning	14. Knowledge discovery abilities 15. Creativity and innovativeness	Supports categories 1 and 2
Structural	6. Team interfaces and collaboration	16. Internal cohesion 17. Working together, team spirit 18. Inter-team bonding	Velocity, Quality, Appropriateness a core category
Structural	7. Tools and methods	19. Availability of tools and infrastructure 20. The efficiency of the tools 21. Enabling communication solutions	Velocity, Quality a core category
Structural	8. Organizational knowledge	22. Knowledge sharing and learning capabilities 23. Knowledge base and access to knowledge	Supports core categories
Structural	9. Architecture	24. Timeliness 25. Technical feasibility 26. Workability	Supports core categories
Structural	10. SWE specific practices, processes and systems	27. Enabling design environment 28. Team efficiency enabling practises and processes 29. Capacity planning 30. Managing dependencies	Supports core categories
Structural	11. Competence management	31. Work transfer driven competence changes 32. Competence management practices 33. Engagement and loyalty care	Supports core categories
Structural	12. Innovativeness (organizational)	34. Innovativeness enablers 35. Innovation management structures	Supports core categories
Structural	13. Management processes, practices and systems	36. General human resource practices, e.g. cultural variety 37. Overall scheduling and capacity planning 38. Processes, systems and practises	Supports core categories
Structural	14. Leadership, company policies and strategy	39. Diverse issues, subclasses not yet available	Supports core categories
Relational	15. Business relationships and networking	40. Not yet available	Appropriateness & supports core categories
Relational	16. Customer loyalty	41. Trust	Enhances appropriateness
Relational	17. Company image	42. Attractiveness	Support core categories.

The research work on developing the measurement framework has produced a baseline model and a concept map and the partner companies have willingly identified several uses for them. For example, the indicator set is used as a check list for improving daily operations.

The common aspect for all of the planned and envisioned uses of the baseline model and its derivatives is monitoring change, but not trying to capture absolute figures. Hence, a comparative measurement approach is amongst the first plans for the DD-SCALE. Particularly, the transfer of development work from one site to another entails uncertainties which impacts can be analysed with the support of the categories and subclasses presented in this paper. A chosen indicator set can be used for estimating the current level of productivity of the original site and the estimated levels of the productivity in the destination site after the work transfer. Eventually, figures can be given to all selected sets and their productivity parameters in order to allow a comparative estimation.

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