INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED15
27-30 JULY 2015, POLITECNICO DI MILANO, ITALY

WORK SAMPLING APPROACH FOR MEASURING INTELLECTUAL CAPITAL ELEMENTS IN PRODUCT DEVELOPMENT CONTEXT

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Abstract

By embracing insights from project management and intellectual capital measurement research fields, basis can be established for development of new performance indicators for monitoring intangible project aspects of individual and team work within the product development context. Focusing on individual and team level of product development projects, data gathering is hampered by constraints of the real organizational environment. Therefore, in this research paper, development of work sampling self-report application is presented which allows data capturing for real-time measurement of intellectual capital elements in a practical and straight-forward way. Preliminary work sampling study was executed in R&D company whose main preocupation is development of the electro-mechanical devices for distribution and transformation of the electrical energy within the energy infrastructure or mass transportation systems. Information about potential trends of particular underperforming values related to the communication and information sharing, innovativeness/ideation and motivation/satisfaction on individual or team level, could provide added value for the project managers and decision makers.

Keywords: Work sampling, Organisation of product development, Intellectual capital, Project management

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

Traditional project management approaches used within the product development (PD) context are often ignoring intangible outputs (such as mindset, behaviour, knowledge, learning, trust). However, in addition to iron triangle perspective (cost, time, quality), project management practice could be seen as a social conduct, defined by history, context, individual values and wider organisational structure framework – actuality of the project (Cicmil et al., 2006). Therefore, extending performance criteria towards intangible aspects of projects (Aronson et al., 2013) and setting up the basis for intellectual capital (IC) evolution measurement within PD context could provide the new insights and allow wider perspective on individual and teamwork performance.

Focusing on individual and team level performance in the real-time within PD projects, data gathering is often hampered by constraints of the real-world organizational environment. Therefore, in this paper, application of work sampling method is presented as a tool for IC performance measurement by capturing data in a practical and straightforward way. Based on IC performance indicators list and network for individual and team levels in product development identified within the VISINEV (www.visinev.org) project, sequence of work sampling entries was formed and work sampling mobile application has been developed. Statistical background of the work sampling technique was used for quantification of individual and team IC performance indicators related to particular product development activities, providing in such way additional perspective on project health and intangible related performance actuality.

2 LITERATURE REVIEW

2.1 Performance indicators for product development

As one of the main components of the project management approaches, performance measurement is required for assuring the project success and its value to the whole organization. As such, measuring performance can provide feedback about process or organization efficiency and effectiveness and increase odds for project and organization success (O'Donnell and Duffy, 2002). Performance indicators are operative part of any performance measurement system, which provide information about accomplishment of the given objective. As such, this approach for performance measurement is practical and easy to understand, causing its wide acceptance in the organizational environment.

For a long period, only a few researchers tackled the issue of performance indicators within the PD context. Among the most recent, Gries and Restrepo (2011) confirmed with the case study that project management performance indicators should be used within the PD context by taking into consideration specificities of the organization, projects and teams. Taylor and Ahmed-Kristensen (2013) identified a set of critical success factors and performance indicators for the global PD environment. From the lean PD point of view, Dombrowski et al. (2013) proposed set of enterprise-specific performance indicators, but without providing metrics for each indicator.

However, none of these researchers was tackling the intangible perspective of the individual and teamwork within PD projects. Intangible perspective of the project is considered as a part of the wider concept called intellectual capital, for which "developments take place in diverse disciplines" (Marr, 2011). This fact motivated the authors to combine insights from the related fields (human resources, organizational psychology) and from the product development, in order to define the list and network of performance indicators related to the intellectual capital elements evolving within development projects (Štorga and Škec, 2014).

2.2 Intellectual capital related performance indicators

Several definitions of intellectual capital exist which can be interpreted in different ways, but the one made by European Commision (2008) prevails in the literature. According to them, intellectual capital can be defined as a combination of activities and intangible resources (human, structural, relational) of an organization. Edvinsson and Sullivan (2008) included the value perspective, claiming that intellectual capital considers "knowledge which can be converted to the value".

Within the whole research field of IC, recently the new question emerged questioning how to measure IC (Dumay, 2009) elements? Modern research paradigm within IC research field is mostly explorative focusing on epistemological discussions about theoretical models (Gonzalez-Loureiro and Figueroa Dorrego, 2012). Although the importance of these research attempts is undeniable, fundamental research level needs to be extended with insights from direct or indirect observations of intellectual capital evolution in the PD organizations and processes.

Accordingly to the literature, the indicators can be divided into two groups: financial and non-financial. In terms of practicality and data gathering aspects, financial indicators (expenditure on R&D/technology purchase, average income from patented products and processes, revenue from new products/total revenue) have their advantages. In contrary, the non-financial indicators proposed in the literature often do not have proper description or metric. Research by Bontis and Fitz-Enz (2002), confirmed that there is an association between both types of measurement indicating consistency between them, despite the fact that non-financial and qualitative indicators are perceived as less objective. However, case study made by (Vuolle et al., 2013) confirmed that many measures are not specific enough to be usable in the real environment. The two crucial aspects of the performance indicator development is to define high relevant performance data and to define valid and robust methodologies for gathering data and mapping it to indicators which could be then used as tool for managing performance (Warhurst, 2002). For capturing intangible aspects of the projects, data gathering have to be conducted in real-world PD organizations what can be cumbersome and hard to achieve.

Because of the specificities of the individual and team work during the PD process, authors selected three different approaches for data gathering: 1) Work sampling; 2) Surveys; and 3) Integration with corporate information systems. While surveys and integration with existing IT systems are quite common for organizational non-financial IC measurement, the work sampling is not usually used in such context and offers new possibilities for quantitative and objective data gathering at individual and team level. Therefore, in this paper, the work sampling approach for collecting data on IC elements within PD projects will be presented.

2.3 Technical background of work sampling

Work sampling is a methodical work measurement approach for estimation of time percentages people spent on execution of activities. It can be found in literature under various names such as “activity sampling”, “ratio delay”, “occurrence sampling”, “snap delay”, but the most common one today is “work sampling” which was firstly introduced by Brisley (1952) (from Badiru, 2013). Technique is based on data collection at specified time intervals as opposed to classical time studies. As the most known application in product development, Robinson used it to examine information behaviours of engineers, but also to analyse how engineers spend their time and which activities and tasks are they performing on a daily basis (Robinson, 2010, 2012).

Underlying principle of work sampling are laws of probability, which enable estimation of proportion of time that was spent on a particular task. After data collection, based on the measured sample of work activities, percentages can be determined.

In order to formulate proper and valid work sampling study, five steps have to be followed: identification of activities which represent main purpose of planned study; estimation of the activity time period (percentage of total time) which is relevant for this study type; determination of the level of precision which is required for a certain study; definition the times when measurement has to be performed; and, recalculation of the number of measurements points that have to be executed to check if the required level of precision will be obtained. In the literature is advised to distribute sample points evenly over days of the work sampling study with the observation point at fixed or random time interval. Exact number of daily measurements depends on the number of participants and duration of the study.

In comparison to other work measurement studies, work sampling offers several benefits. It is a simple method and therefore participants with minimal training can conduct the sampling. The costs are much lower compared to continuous observation. In addition, it enables immediate data collection and participants are not required to estimate the amount of time they spend on the task. Also, certain disadvantages have to be taken into consideration. For instance, if analysed process is going through change, work sampling results will not be representative.

2.4 Data gathering approaches for work sampling

Work sampling data can be collected by using observations (e.g. Buchholz et al., 1996) or self-report (e.g. Robinson 2010) methods. Observations approach is resource-intensive because it implies continuous monitoring of participants (sometimes even only one participant at the time). According to

Finkler et al. (1993), observation is more appropriate technique if study is performed in a limited area (e.g. nurses in the hospital, workers in shop floor). Self-reporting is usually conducted by using activity logs (Finkler et al., 1993), work diaries (Pedgley, 2010) and questionnaires (Lowe et al., 2004). With the advancement of technology, personal telecommunication devices (pagers) were initially used to indicate participants about the time to note self-report information (still hardcopy checklist).

In order to improve limitations of pager approach and decrease effort made by participants, (writing the logs) the personal digital assistants (PDAs) start to be used for capturing data in health care practice. Inspired by that, Robinson (2010, 2012) proposed usage of PDAs for work sampling of engineering activities during product development process. PDA application enabled series of menus with an extensive list of entry items; participants were able to insert data about a specific activity in a fast manner. In addition, PDAs provided the opportunity to control and measure the delay between the moment when alarm is emitted and when questionnaire is fulfilled.

Nowadays, PDA is obsolete technology, and, therefore, the need to transfer to newer technologies was recognised in presented research. Smartphones are nowadays easily available, and people feel comfortable while using their intuitive and practical touch-based devices. Only small number of work sampling mobile applications were found, and central issue is their inflexibility and missing option to modify existing input entries accordingly to the particular needs of the research. Combining multidimensional work sampling with advantages offered by mobile applications technology, for the purpose of the research presented in this paper, the new application was developed for gathering real-time data about individual and team work activities in PD process as the source for determination of the IC performance indicators.

3 DATA GATHERING BY WORK SAMPLING MOBILE APPLICATION

For the assessment of the individual and teamwork IC performance, the list of 65 indicators was developed and networked (Štorga and Škec 2014), but also classified within following categories: competences and knowledge (data is not collected using work sampling and for that reason indicators are not included in this paper); communication and information exchange; innovativeness and ideation capability; and motivation and satisfaction.

Table 1. Excerpt from the list of identified IC performance indicators for which data will be collected by using work sampling approach

Indicator label	Name of indicator	Calculation of indicator
Individual level		
Communication and information sharing		
CI_IN3	Discussions (informal)	percentage of time (0%-100%)
CI_IN4	Meetings (formal)	percentage of time (0%-100%)
CI_IN5	Team meetings	percentage of time (0%-100%)
CI_IN6	Information received per period	percentage of time (0%-100%)
CI_IN7	% of recieved information relevant for the task	percentage of time spent on receiving information (0%-100%)
CI_IN8	% of information received directly from colleague or via some other channel	percentage of time spent on receiving information (0%-100%)
CI_IN9	Information sent per period	percentage of time (0%-100%)
CI_IN10	% of sent information relevant for the task	percentage of time spent on sending information (0%-100%)
CI_IN11	% of sent information directly to colleague or via some other channel	percentage of time spent on sending information (0%-100%)
CI_IN12	Information processing	percentage of time (0%-100%)
CI_IN13	% of relevant information processing activities	percentage of time spent on information processing (0%-100%)
Motivation and satisfaction		
MS_IN1	Personal motivation	rating (1-5)
Innovativeness and ideation		
II_IN1	Number of innovation/improvement activities regarding product	number of product innovation/improvement activities
II_IN2	% of relevant innovation/improvement activities regarding product	percentage of product innovation/improvement activities (0%-100%)
II_IN3	Number of innovation/improvement activities regarding other domains	number of other innovation/improvement activities
II_IN4	% of relevant innovation/improvement activities regarding other domains	percentage of other innovation/improvement activities (0%-100%)
Team level		
Communication and information sharing		
CI_TM1	To what extent the team members re-use knowledge (solutions/contributions) from internal sources	percentage of time (0%-100%)
CI_TM2	To what extent the team members re-use knowledge (solutions/contributions) from external sources	percentage of time (0%-100%)
Motivation and satisfaction		
MS_TM1	Team employee motivation	rating (1-5)
MS_TM3	% of activities done with lower motivation	percentage of time (0%-100%)
MS_TM4	% of irrevant activities for their assignment	percentage of time (0%-100%)
Innovativeness and ideation		
II_TM5	Number of innovation/improvement sessions during team activities regarding product	number of product innovation/improvement sessions
II_TM6	% of relevant innovation/improvement sessions during team activities regarding product	percentage of product innovation/improvement sessions (0%-100%)
II_TM7	Number of innovation/improvement sessions during team activities reagarding other domains	number of other innovation/improvement sessions
II_TM8	% of relevant innovation/improvement sessions during team activities reagarding other domains	percentage of other innovation/improvement sessions (0%-100%)

Since work sampling is a generic approach and irrelevant of the application, there was a necessity to customise entry items for data gathering accordingly to the indictors list. Apparent distinction between indicators and data gathering method for their measures should not be left unnoticed. Besides surveys and data that could be extracted from the existing IT infrastructure, a certain amount of indicators requires work sampling approach (Table 1). Inspired by work of Robinson (2010) and by using analogy with electronic diary concept, work sampling application was conceived as a sequence of screens with predefined single-choice and multi-choice menus to enable fast and easy input of needed data (Figure 1).

Figure 1. Screenshots of work sampling application developed for IC performance indicators data gathering

3.1 Development of the input entries menus for work sampling application

Initial lists of data entries were created based on work sampling literature review relevant to engineering activities sampling. Contextual input entries for product development were set up to facilitate gathering data about behaviour and provide wider perspective on individual technical/administrative and teamwork activities relevant for IC performance. Definition process resulted with nine groups of input entries (some of the options for specific data entries are listed in brackets):

1. Work context (solo-technical, solo-administrative, teamwork, break)
2. Individual or teamwork activity type (such as Discussion, Meeting, Report)
3. Product development activity (following the Sim and Duffy (2003) ontology of design activities such as Planning, Analysis, Decision making, Conceptualization/Design, Innovation)
4. Activity context (such as technical-product, technical-process)
5. Party (team members - there is a possibility to select each one of them based on organizational structure data that is imported prior to sampling episode)
6. Manner (face-to-face, email, teleconference, etc.)
7. Information transaction (following the Cash et al. (2014) such as seeking, receiving, giving)
8. Relevance of information for current activity/project phase (grade 1-5)
9. Motivation for activity (grade 1-5)

While creation of some entry items was straightforward, others required more attention. For the creation of PD activity list, job analysis reports were received for each role in the PD teams from the human resources department of two companies that participated in the study (automotive and energy sector). Some activities from Sim and Duffy's ontology were considered as too abstract for the study and therefore they had to be aggregated within the same, but more general category. On the other hand, within the "Party" list, the project members were listed based on current organisational structures.

3.2 Mapping gathered data to identified IC indicators

Statistical nature of work sampling method enables acquiring of quantitative data about actuality of corresponding IC performance indicators (Table 1). However, in order to obtain indicator values, data gathered using work sampling approach needs to be transformed and mapped. The most common method of mapping between collected sample points data vectors and performance indicators for individual and team level is determination of the ratio between particular sample point for specific item (as a numerator) and overall number of sample points (as a denominator). For example, to calculate the value of indicator *Discussions*, it is required to compute the percentage of total time that each team member spent on discussions (informal meetings). Because of the high number of the sample points, these calculations are statistically relevant and allow quantification of usually not easily quantifiable aspects of intellectual capital related performance. Second group of indicators that emanates from work sampling data are also based on ratio values, but represents percentage of particular time spent on a particular activity (e.g. *percentage of relevant innovation/improvement activities regarding product*). Third group of indicators are *level of motivation* and *relevance of information* which are assessed using a quantitative scale from 1 to 5. Fourth group of indicators is taking into consideration previous group of indicators, and combine them with complex measures with work sampling ratios. Combination of different perspectives allows calculation of indicator values such as *percentage of activities done with lower motivation*. In the last group, we can categorize indicators which are used for direct measurement of the occurrence of particular activity, such as *number of innovation/improvement activities regarding product*.

4 CASE STUDY

4.1 Work sampling application implementation

Since work sampling application was developed from the scratch, initially researchers tested its features and possibilities to resolve bugs and confirm basic functionalities. Afterwards, the IT representatives of the two companies conducted preliminary testing of the technical aspects (deployment, setup, etc.) and checked its concordance with a diverse set of mobile phones and different versions of target operating system (Android). After technical issues had been resolved, the test work sampling session was set within the R&D department of one company. Work sampling application was presented to the participants during the group meeting where goals and expectations of the experiment were given. In addition, application manual was created with written instructions how-to-use it and detailed descriptions of the each entry item existing on the menu lists. Participants were asked to validate the entry items by using the application during the test period and that time was also used for them to become more familiar with the usage of application and its features. Informal discussions were on-going during the sampling time with participants in order to clarify all issues and misunderstandings. After participants had become familiar with the application, it took about 15 seconds to enter the data for emitted alarm.

4.2 Work sampling session setup

Finally, work sampling session was set up for 10 working days (two weeks), with randomized number of alarms (7-10) per day and with minimum time distance of half hour between two alarms and maximum 1,5 hour. In total, 15 participants were selected to sample their activities (13 technical team members, technical project manager, head of the department). The projects that have been selected are related to the development of the embedded control systems in the field of electrical power and rail transportation. Projects were in different stages of the project development, with the different workload distribution of the participants accordingly. Most of the participants are working on more than half of selected projects at the time of sampling. As the result, sampling data vectors containing input entries were recorded and analysed. Due to the page limitation, only portion of the results has been shown in the following sections in order to illustrate the results of the mapping of the work sampling data to the IC performance indicators.

4.3 Results and discussion

4.3.1 Data overview

Overall, across all 15 participants, 1357 alarms were emitted during working hours (i.e., excluding weekend) over the course of the study, of which participants entered data on 1194 occasions. Each participant responded a mean of 79,6 alarms during the work sampling period, which means they answered 7,96 alarms per day. What is of particular importance, the 69,3% of the alarms were answered within first 15 minutes after alarm is emitted, and additional 10,9% up to the half hour after the alarm what makes results representative to draw conclusion about study period.

By application of work sampling equations, it can be determined that this number of valid sample-points enables detection of a task accounting for 5% of working time, with +/- 20% precision, and 90% confidence in that accuracy (Robinson, 2010). So, if a particular task was calculated to account for 5% of working time (i.e., 24 minutes per standard 8-hour working day), then it could be stated with

90% confidence that the actual figure was between 4% and 6% (i.e., between 19,2 and 28,8 minutes per day). Time percentages exceeding 5% could be stated with greater confidence and precision than this and vice versa for time percentages lower than 5%.

4.3.2 Overall analysis of individual and teamwork

Work sampling results showed that *individual technical* activities are dominating the responses with 68% of total number of sampling points, being followed by *teamwork* activities with 15%, *individual administrative* activities with 7% and 10% of *breaks*. The results revealed that participants when working *individually* have spent most time engaged in *electronics* related development activities followed by *software* what was expected when knowing the background of the projects and professional profile of participants. In the same time, teamwork activities were dominated by *informal discussions* focusing on the same context and *formal meetings* of two persons focusing on the issues related to the *people* (team members). The most of the *reports* that have been prepared as the result of the *teamwork* activities during the observed period were focusing on the *software* but also on issues related to the *people* and *facilities*. Relative *motivation in individual* and *teamwork* was highest for the activities related to the *product context*, followed by *process-related context* for *individual* work and *facility* issues resolved in *teamwork*. The percentage of time that participants spent engaged in different type of activities within *individual technical* and *team*work in combination with *information transaction* nature, happening within the particular activity, are shown in Table 2.

Table 2. Work type versus information transaction nature of activities and relevance of information used for a particular activity

		Giving information			Receiving information			Processing information			Information seeking						Overall		
											Internal source			External source					
Work type		CR	PT	RI	CR	PT	RI	CR	PT	RI	CR	PT	RI	CR	PT	RI	CR	PT	RI
Solo-technical work		44	4,72%	3,55	31	3,32%	3,60	609	65,27%	4,25	70	7,50%	4,29	8	0,86%	3,88	762	81,67%	4,19
Management activities	Planning							4	0,43%	3,50	1	0,11%	4,00				5	0,54%	3,60
	Resolving conflicts	2	0,21%	5,00	1	0,11%	5,00	7	0,75%	4,71							10	1,07%	4,80
	Resource assignment	1	0,11%	4,00				2	0,21%	4,00	1	0,11%	2,00				4	0,43%	3,50
	Negotitation							4	0,43%	5,00							4	0,43%	5,00
Evaluation activities	Analysis	2	0,21%	3,00	15	1,61%	3,36	50	5,36%	3,92	3	0,32%	4,67	1	0,11%	3,00	71	7,61%	3,80
	Decision making	3	0,32%	3,33				6	0,64%	3,50	2	0,21%	5,00				11	1,18%	3,73
	Measurement				3	0,32%	4,67	29	3,11%	4,79	50	5,36%	4,40	1	0,11%	4,00	83	8,90%	4,54
	Monitoring	1	0,11%	5,00				18	1,93%	4,78							19	2,04%	4,79
	Selecting/evaluating	1	0,11%	3,00				3	0,32%	4,33							4	0,43%	4,00
Definition activities	Conceptualization/design	1	0,11%	3,00	1	0,11%	5,00	258	27,65%	4,48	1	0,11%	4,00				261	27,97%	4,48
	Detailing/coding	15	1,61%	3,93	5	0,54%	4,20	174	18,65%	4,38	1	0,11%	3,00	3	0,32%	3,33	198	21,22%	4,32
	Innovation/improvement	2	0,21%	2,00	2	0,21%	4,50	7	0,75%	3,29				3	0,32%	4,67	14	1,50%	3,57
User support		2	0,21%	3,50							1	0,11%	4,00				3	0,32%	3,67
Reporting					1	0,11%	2,00	40	4,29%	2,25	3	0,32%	2,00				44	4,72%	2,23
Sales/procurement		6	0,64%	3,00				1	0,11%	3,00							7	0,75%	3,00
Other individual		8	0,86%	3,38	3	0,32%	1,67	6	0,64%	4,33	7	0,75%	4,71				24	2,57%	3,79
Team work		34	3,64%	3,91	41	4,39%	3,46	93	9,97%	3,95				3	0,32%	4,00	171	18,33%	3,82
Management activities	Planning	5	0,54%	4,00	8	0,86%	4,13	14	1,50%	4,00							27	2,89%	4,04
	Resolving conflicts	2	0,21%	3,50	3	0,32%	4,67	4	0,43%	3,75				1	0,11%	4,00	10	1,07%	4,00
	Resource assignment	1	0,11%	3,00	3	0,32%	3,00	2	0,21%	4,00							6	0,64%	3,33
Evaluation activities	Analysis	2	0,21%	5,00	4	0,43%	3,75	19	2,04%	3,84							25	2,68%	3,92
	Decision making	4	0,43%	4,25				9	0,96%	4,00				2	0,21%	4,00	15	1,61%	4,07
	Measurement				2	0,21%	4,50	14	1,50%	4,50							16	1,71%	4,50
	Monitoring							1	0,11%	5,00							1	0,11%	5,00
	Selecting/evaluating	1	0,11%	4,00				3	0,32%	4,00							4	0,43%	4,00
Definition activities	Conceptualization/design	4	0,43%	4,25	5	0,54%	4,00	14	1,50%	4,21							23	2,47%	4,17
	Detailing/coding				1	0,11%	5,00										1	0,11%	5,00
	Innovation/improvement	3	0,32%	4,67	4	0,43%	3,00	7	0,75%	3,43							14	1,50%	3,57
User support		7	0,75%	4,14	1	0,11%	2,00	2	0,21%	3,50							10	1,07%	3,80
Reporting		1	0,11%	3,00	3	0,32%	2,67	1	0,11%	2,00							5	0,54%	2,60
Sales/procurement		3	0,32%	2,67	1	0,11%	3,00	1	0,11%	4,00							5	0,54%	3,00
Other teamwork		1	0,11%	1,00	6	0,64%	2,00	2	0,21%	1,50							9	0,96%	1,78
Overall		78	8,36%	3,71	72	7,72%	3,52	702	75,24%	4,21	70	7,50%	4,29	11	1,18%	3,91	933	100,00%	4,12

Legend: CR – count of responses, PT – percentage of total time, RI – level of information relevance

In additional column, *relevance of the information* for specific project phase and activity were presented. The results revealed that participants when working *solo* spent most time engaged in *processing information* followed by *information seeking* (from internal sources), while working in *teams* the distribution between *information giving, receiving*, and *processing* is more balanced. The majority of the *giving information transactions* for *individual* work are happening during *product definition activities* (*detailing/coding*) while during *teamwork* the *user support* is dominating the *management, evaluation* and *definition* activities. *Receiving information* from *solo technical* work is biggest during *evaluation activities* (analysis), while in *teamwork management* activities focusing on *planning* are leading. *Processing information* in *individual work* is mostly present during *definition*

activities (*conceptualisation/design* and *detailing/coding*), while during the *teamwork* the *evaluation activities* (*analysis and measurement*) are dominating. *Information seeking* from *internal sources* is intensive during *measurement* activities of *individual technical* work while *external sources* are consulted mostly during *improvement/innovation* activities. In the *teamwork, external sources* are primarily referred during the *decision-making*.
Of course, it has to be taken into consideration, that for stronger conclusions, more sample points are needed and longer study than this preliminary one.
Although the experiment made by Robinson (2010) had some differences in terms of categorizations and menu items, comparison with his research can confirm value trends and ratios of different activities. However, in this study more technical aspect is present, what can be seen in higher percentages (85,35% > 62,92%) of activities with technical context (product and process-related). Also, lower percentage of technical teamwork (11,29% < 24,08%) can be perceived in this study, correlated with the later project phases during the sampling time. Both differences can be connected with late phase of one of the sampled projects. That particular project phase was related to detailed design of electronics boards and hardware which is by the default solo technical work.

4.3.3 IC performance indicators analysis

As was explained before, the work sampling data gathering method is applied only to portion of the IC performance indicators on individual and team level mostly focusing on innovativeness/ideation, motivation/satisfaction and communication/information sharing. To illustrate how it looks like after gathered data is transformed into indicators, several graphs representing the change of the single indicators value in temporal dynamics is presented and discussed in this section.
For example, within the innovativeness/ideation category on the individual level, the key indicator is *number of innovation/improvement activities regarding product (and other domains)* and dynamics of the value change in correspondence to the product context is shown in the Figure 2 (left side). To ensure shared understanding of the innovation/improvement activity, in application manual it was defined as "searching and analyzing new ideas and solutions in terms of product or process improvement". It can be easily read from the graph that the majority of the innovation sessions was related to the software issues. For the team level, the same indicator value dynamics during the observed period is shown on the right side of the graph. Software related issues are dominating this as well, but in addition to the product context related innovation, teamwork was also focused on the process related innovations (indicator about innovation/improvement activities for other domains).

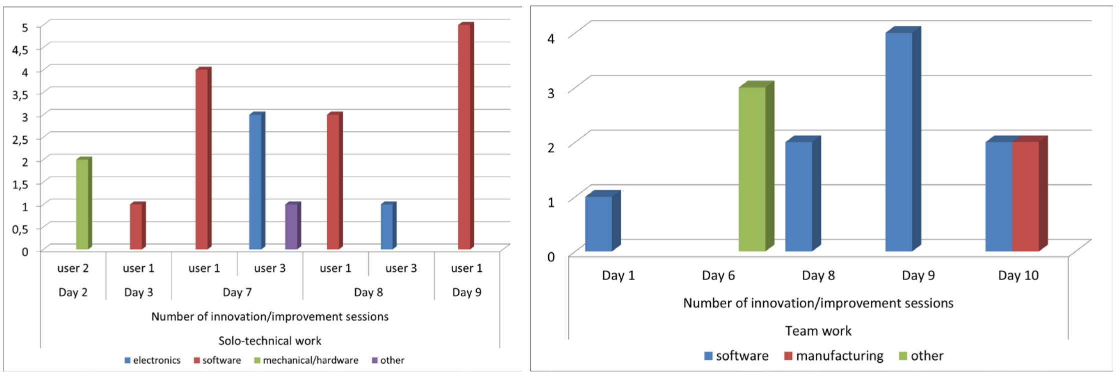

Figure 2. Innovativeness/ideation performance IC performance indicator value change over the sampling time - the number of innovation/improvement activities regarding product (and other domains) for individual (left) and team level (right)

Another example is communication and information sharing category of IC performance indicators on the individual level, where ratio of the different activities within the working time of each is calculated (Figure 3, left side). The trends in solo and teamwork activities, when correlated with the context are providing a clear picture of the individual communication/information sharing profile over the observed period. On the right side of the Figure 3, ratio of activities with different motivation levels is presented for work sampling period. When correlated with the context of the teamwork activities it provides a clear picture of the teamwork motivation profile over the observed period.

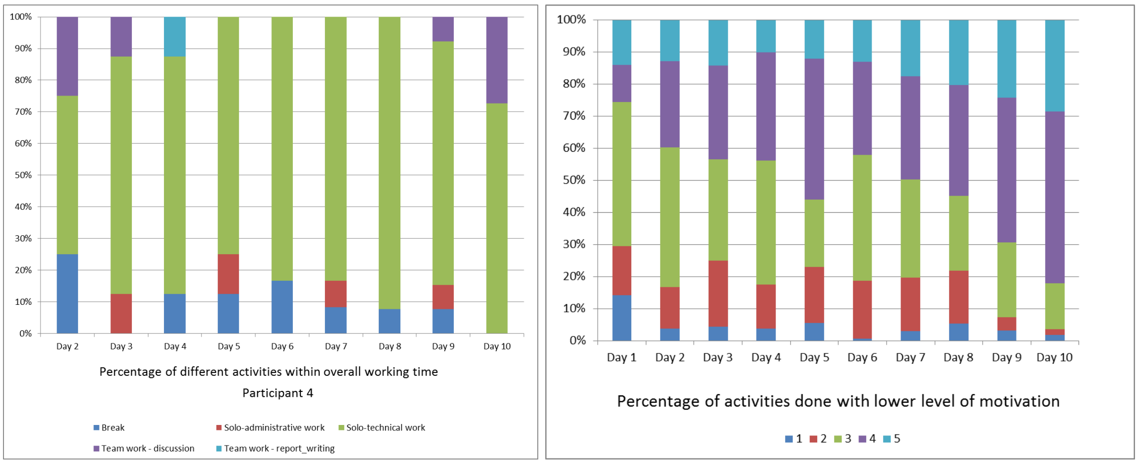

Figure 3. Communication/information sharing IC performance indicator value change over the time - percentages of solo technical, solo administrative, discussions (informal), meetings (formal – 2 persons) and team meetings for an individual (e.g. participant 4) (left) and percentage of activities done with lower level of motivation (right)

Of course, research limitations have to be taken into consideration. Besides limitations which are inherent in the work sampling approach, self-reporting as an approach also has its drawbacks. Any research which relies on self-reporting is susceptible to various biases caused by participant feelings and motivation. Also, there is possibility that they do not perceive or understand different phenomena in a same way. To reduce those biases, they were provided with application manual, and they were encouraged to contact authors in case of any misunderstanding related to the application. In addition, self-reporting approach was facilitated by using straightforward predefined single- and multi-choice menus.

Above described examples is only the first step in IC performance indicators analysis. When combined with data gathered from surveys and existing IT system, IC performance indicators are aggregated to illustrate dynamics of each of the four IC elements categories on individual and team level, enabling analysis of the trends and predictions of the future values. As such, they are supporting team and organisational managers making decisions relevant for the projects during the project execution based on the actual performance of the individuals and teams participating in the projects.

5 CONCLUSION

Application of the work sampling method for data gathering enabled additional dimension of real-time project performance assessment based on the actual data. Having the information about potential negative trends or indicators of particular underperforming values for the project execution related to the knowledge and competences, communication and information sharing, innovativeness/ideation and motivation/satisfaction on individual or team level, could provide added value for the organisation. Bringing the performance indicators of intangible output aspects in traditional project management tools, could complement traditional project management practice and shed the light on phenomena that are emerging when sociotechnical perspective is included (knowledge transfer, organisational learning, innovation but also risks related to the critical individuals and team composition).

Work sampling enables fewer intrusive data gathering needed for longitudinal studies performed in real working environments and has proven as very efficient tool for product development context that could be quickly adopted in daily practice. Continuous collection of the data related to the activities and performance is central presumption for studying long-term effect of the individual and teamwork on organisational business value and organisational performance in terms of the innovation, market growth and competitiveness.

Beside the detailed statistical analysis of the work sampling results combined with dynamic network analysis that will be performed on networks resulting from work sampling (social network, knowledge network, resource network, task networks, etc.), further research will focus on the development of the aggregation model that will enable understanding the organisational level performance. Combining the intangible perspective with tangible outputs into a single framework is the final goal that should result in new and extended tools and methods for complex engineering projects management.

REFERENCES

Aronson, Z. H., Shenhar, A. J. and Patanakul, P. (2013) Managing the Intangible Aspects of a Project: The Affect of Vision, Artifacts, and Leader Values on Project Spirit and Success in Technology-Driven Projects. Project Management Journal, Vol. 44, No. 1, pp. 35–58.

Badiru Adedeji B., (2013) Handbook of Industrial and Systems Engineering, CRC Press, Second Edition.

Bontis, N. and Fitz-enz, J., (2002) Intellectual capital ROI: a causal map of human capital antecedents and consequents. Journal of Intellectual Capital, Vol. 3 No. 3, pp. 223–247.

Brisley, C. L. (1952) How you can put work sampling to work. Factory Management and Maintenance, pp. 83-89.

Buchholz, B., Paquet, V., Punnett, L., Lee, D. and Moir, S. (1996) PATH: A Work Sampling-based Approach

Cash, P., Stanković, T. and Štorga, M. (2013) Using visual information analysis to explore complex patterns in the activity of designers, Design Studies, Elsevier Vol. 35, No. 1, 2014

Cicmil, S., Williams, T., Thomas, J. and Hodgson, D. (2006) Rethinking Project Management; Researching the actuality of projects. International Journal of Project Management, Vol. 24, No. 8, pp. 675-686.

Dombrowski U., Schmidtchen K., and D. Ebentreich, D. (2013) Balanced Key Performance Indicators in Product Development, International Journal of Materials, Mechanics and Manufacturing, Vol. 1, No. 1, pp. 27-31.

Dumay, J. C., (2009) Intellectual capital measurement: a critical approach. Journal of Intellectual Capital, Vol. 10, No. 2, pp.190 – 210.

Edvinsson, L. and Sullivan, P. (1996) Developing a model for managing intellectual capital. European Management Journal, Vol. 14, No. 4, pp. 356-364.

European Commission (2006) Reporting Intellectual capital to augment research, development and innovation in SMEs. Report to the commission of the high level expert group on RICARDIS, Encourage corporate measuring and reporting on research and other forms of intellectual capital, European Commission.

Finkler, S.A., Knickman, J.R., Hendrikson, G., Lipkin, M.J., Thompson, W.G. (1993) A comparison of work-sampling and time-motion techniques for studies in health service research. Health Services Research, Vol. 28, No. 5, pp. 577–602.

Gonzalez-Loureiro, M. and Figueroa Dorrego, P. (2012) Intellectual capital and system of innovation: What really matters at innovative SMEs. Intangible Capital, Vol. 8, No. 2, pp. 239-274.

Gries, B., and Restrepo J. (2011) KPI Measurement in Engineering Design - A Case Study. Proceedings of the 18th International Conference on Engineering Design (ICED 11), Vol. 1: Design Processes, Lyngby/Copenhagen, Denmark, 15.-19.08.2011, Design Society, pp. 531-537.

Lowe, A., McMahon, C. and Culley, S. (2004) Information access, storage and use by engineering designers, part 1. The Journal of the Institution of Engineering Designers, Vol. 30, No. 2, pp. 30-32.

Marr, B. (2005) Introduction, In Perspectives on Intellectual Capital, edited by Bernard Marr, Butterworth-Heinemann, Boston.

O'Donnell, F. J. and Duffy, A. H. B. (2002) Modelling design development performance. International Journal of Operations & Production Management, Vol. 22, No. 11, pp. 1198-1221.

Pedgley, O. (2007) Capturing and analysing own design activity. Design Studies, Vol. 28, No. 5, pp. 463-483.

Robinson, M. A. (2010) An empirical analysis of engineers' information behaviors. Journal of the American Society for Information Science and Technology, Vol. 61, No. 4, pp. 640-658.

Robinson, M. A. (2012) How design engineers spend their time: Job content and task satisfaction. Design Studies, Vol. 33, No. 4, pp. 391-425.

Sim, S-K. and Duffy, A. H. B. (2003) Towards an ontology of generic design activities. Research in Engineering Design (RED), Vol. 14, No. 4, pp. 220-223.

Štorga, M., Škec, S. (2014), Intellectual Capital Performance Indicators for Complex Project Management, Proceedings of International Conference on Advanced Design Research and Education (ICADRE14), Singapore, pp. 89-93.

Taylor, T. P., and Ahmed-Kristensen, S. (2013) Performance Measurement in Global Product Development. Proceedings of the 19th International Conference on Engineering Design (ICED13), Vol.9: Design Methods and Tools, Seoul, Korea, 19-22.08.2013, pp. 207-216.

Vuolle, M., Lönnqvist, A., and van der Meer, J. (2009) Measuring the intangible aspects of an R&D project. Measuring Business Excellence, Vol. 13, No. 2, pp. 25-33.

Warhurst, A. (2002) Sustainability indicators and sustainability performance management, working paper No. 43, Institute for Environment and Development, London.

ACKNOWLEDGMENTS

This paper reports work funded by Ministry of Science, Education and Sports of the Republic of Croatia, and Croatian Science Fundation MInMED project (www.minmed.org).