APEM journal
Advances in Production Engineering & Management
Volume 12 | Number 4 | December 2017 | pp 375–387
https://doi.org/10.14743/apem2017.4.265
ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Work sampling for the production development: A case study of a supplier in European automotive industry

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A B S T R A C T

Effective development of production processes within modern engineering projects requires project management to take into consideration the socio-technical project aspects, such as insights into individual and team work, including how much time team members spend on different activities, how they communicate, within what context and in what manner. The paper reports on a self-reporting work sampling approach developed and tailored for the production development and the application of the approach in an automotive industry supplier company. A case study was conducted in a Tier 1 development and manufacturing supplier for the automotive industry in EU. Although the approach requires a significant amount of preparation efforts to configure the tools and reduce participants self-reporting bias, it is less intrusive during data collection as it does not require the presence of researchers. Results provide insights into team members' work type engagement and how their activity was coupled with the context, the manner and the nature of information transaction utilized. Project managers can use these insights to tailor workloads and modify team composition to improve collaboration, coordination and information exchange.

A R T I C L E   I N F O

Keywords:
Automotive industry
Production development
Project management
Teamwork
Work sampling

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Article history:
Received 24 February 2017
Revised 23 October 2017
Accepted 26 October 2017

1. Introduction

Product realization can be defined as a set of activities integrating product design and production development to deliver products that meet the needs of customers [1]. The benefits of the integrated development are particularly manifested within the narrow time frame of modern engineering projects. The integrated approach to development of new products has been well embraced, with automotive industry being the front-line example. To provide short time-to-market, automotive original equipment manufacturers (OEMs) are forced to integrate product- and production-related activities [2] and involve suppliers from early phases of the product development [3]. Nevertheless, the activities of production development are often ignored within product development models even though it provides crucial steps in delivering marketable products [4].

Production development can be perceived as a concept related to development of effective production processes and improvement of production ability [1]. Activities of production development start at the very beginning of product realization (product conception and design), when important aspects of manufacturing technologies and materials are defined. Successful integration and efficient development rely mostly on well-established coordination and cooperation [5] and resource allocation by the management [1] in both OEMs and supplier organizations. Moreover, the increasing need for organizational innovation as a source of competitive advantage asks for new managerial practices not only to cope with development of complex products but also to reduce administrative costs and improve workplace satisfaction [6].

Traditionally, the management approaches in product and production development context are often focused solely on the technical aspects of project management [7], such as planning, scheduling, risk management, cost control, etc. Recently, the progress of information technology has significantly advanced these technical aspects of project management and made them more efficient [7]. Despite the availability of different tools, effective project management needs to take into consideration also the socio-technical perspective [8], since it is the people that are the centre of projects. Project managers thus require understanding and timely insight into the working processes, the teamwork and the working environment in which the developers are engaged.

To better understand the socio-technical aspects of production development, there is a need to collect data for the activity of each participant in the development process. Such data collection often implies logbooks and retrospective interviews or questionnaires. However, in recent years, the number of new data gathering approaches significantly increased by using digital technologies such as the use wearable recording equipment (photo, video and audio) and tracking software [9]. Building on these premises, a self-reporting approach for work sampling has been developed and tailored for the production development context. Work sampling is a methodical approach used for measuring the timeshare individuals spend performing different activities, based on collecting data at specific time intervals. In comparison to other work measurement methods, work sampling is perceived as a more reliable, valid and practical approach [10].

Several aspects of scientific contribution have been identified within the extent of this paper. Firstly, a methodology for a longitudinal work sampling research in organizational environment has been developed to allow conducting this type of research in production development context. Work sampling in production context tends to be applied mainly for shop floor workers [11], whereas in presented research it is introduced within the development environment. Secondly, insights from the literature and organizational settings have been applied to develop comprehensive self-reporting menu structures for the production development context, which were then validated in a case study. Thirdly, the paper reports on a unique empirical study of work measurement conducted in production development, at a supplier level in automotive industry, and reveals rich insights on working in that context. Besides the analysis of individual work, the presented study includes the team perspective of production development activities which was neglected in previous research. Finally, the paper describes a more efficient method of self-report work sampling and, as such, allows the transition from research to practical use in organizations.

2. Methodology

The implementation of the work sampling approach required the development of a methodology for longitudinal work sampling research in organizational environment. The methodology consists of five main steps as illustrated in Fig. 1. The first step combines literature review and discussion with representatives of the organization in which the case study takes place. In the second step the work sampling method is adapted based on the insights obtained from the literature and the organizations. The adaptation of the method is followed by the development of a mobile application tool which simplifies and speeds up the self-reporting approach. After the work sampling application's functionality is verified, it is introduced within the case study organization, as the fourth methodology step. At last, the validation of the collected data and obtained insights can be performed by means of interviews and questionnaires performed on study participants.

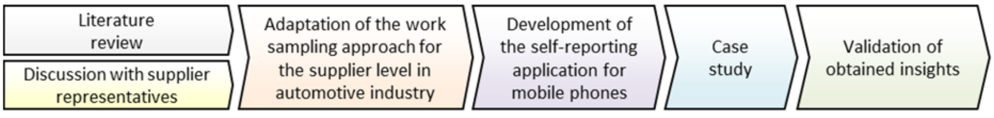

Fig. 1 An overview of the research methodology

2.1 Insights from the literature and the discussions with supplier representatives

Current trends of mass vehicle customization demand an ongoing improvement of efficiency and flexibility of production processes of both the OEMs and their suppliers [2]. Modular designs allow automotive OEMs to shift from outsourcing single components to more valuable and physically larger independent modules [3, 12]. Following this, parts of design and production are outsourced to suppliers. The competitiveness of OEMs thus depends largely on the performance of suppliers and their production development teams.

To increase understanding on activity of production development teams, researchers have been studying the process using approaches such as observations, interviews, document studies and surveys [13, 14]. Besides measuring the work of individual team members, a special importance has been put on teamwork aspects of development activities. Recent studies thus emphasize that collaborative performance should not be overlooked when teams are composed [15]. Therefore, to understand better how production development is conducted, participants of the process must be observed within the team and teamwork context.

In the context of product realization, a team is defined as a small group of individuals which have complementary abilities and are responsible for achieving their common goals [12]. Teamwork is related to the degree of cooperation between the members of the team involved in the process. Team members have their own behaviour patterns, different expectations and understanding of processes and products. Key part of each production development process is to achieve a common understanding of the objectives, despite individual mental models.

During the product and production development process, teams have relatively stable structure and usually work together on several projects [16]. It is common for each team member to be responsible for specific tasks depending on their competence. Although engineers work individually most of the time [16], the need for communication and interaction is continuous. The communicated information are influenced by their organizational and social context thus the communication embraces different contexts of engineering activities such as stakeholder, employee and project issues [17].

In research studies related to the analysis of individual and team work often quite rough and vague measures are used, thereby preventing simultaneous analysis of different production development aspects. Hence, as part of this research paper, analysis of different aspects of individual and team work has been done by analysing how much time individuals spent on different activities, how they communicated, within what context and in what manner. The work sampling approach provided insight into how individuals and team as a whole conduct their activities.

The best-known application of work sampling in the development context is the study conducted by Robinson in a blue-chip international manufacturing engineering organization [18]. He studied the behaviour of engineers across the organization in terms of information use and time spent during the development process [18]. Furthermore, the study by Škec *et al*. [19] represents the applications of here described work sampling approach in the context of product development, within an SME whose activities are focused on the design of systems for the generation, distribution and transformation of electrical energy.

In this paper, the work sampling is applied for a team in the production office context, to measure the timeshare of development-related activities of team members. It is argued that the possession of such type of objectivized data about the conducted development process can support the decision-making of project managers when they are confronted with a task of team composition or team member allocation. The self-reporting approach to work sampling overcomes some of the inherent drawbacks of design ethnography methods (e.g. significant effort because research subject is followed personally) and offers new opportunities for a simplified and more accurate data collection process. Sampling of work activities in such way offers possibility to explore multiple aspects of working content and context. By analysing collected data, more embracive picture of the individual and team work could be obtained.

Discussion with supplier representatives within the automotive industry added further understanding needed to build the case study, such as organization's contextual information, project types and project-based team composition strategies.

2.2 Adaptation of the work sampling approach

Before applying it in a case study, the work sampling approach had to be adapted to the specific context and embedded within a tool that is practical for the study participants to use. A series of menus and menu items were developed to include the aspects of individual and team work identified in production development within automotive industry and allow a predefined data entry. The menu structure will be only briefly explained. Comprehensive description of menus and menu items is available in Škec *et al.* [19]. The self-reporting menu structure (Table 1) includes several scenarios, based on the menu items selected in each menu.

Table 1 Menu structure of the work sampling application developed for the case study context

	Activity type		Activity		Context	Party	Manner	Information transaction
Teamwork	Discussion (informal)	Management activities	Planning	Designing the product	Electronics	Team member 1	Face-to-face	Giving information
			Resolving conflicts		Mechanical/ Hardware		Telephone	
			Resource assignment			Team member 2	Video conference	Receiving information
			Negotiation		Software		Email	
		Evaluation activities	Analysis/Simulation	Designing the process	Manufacturing/ Deploying	Team member 3	Engineering software tools	
			Decision making					Processing information (group thinking)
	Meeting (formal)		FMEA		Logistics/Installation	Team member 4	Office software tools	
			Measurement/Testing		Maintenance/Servicing			
			Monitoring/Reviewing		Disposal/Reusing	Team member X	ERP	Exchanging information
		Definition activities	Conceptual./Design		Administrative	Customer	PDM/PLM	
			Detailing/Coding				Internet	
	Presentation/ Reporting		Ideation/Improvement		People/Team members	Supplier	Knowledge base	Requesting information
			Documenting				Paper misc	
			Prototype realization		Facilities/Infrastructure	Other-internal	Whiteboard/ Smart board	
			Sales/Procurement					Searching for information
			User support		Other Teamwork context	Other-external	Other team manner	
			Other Teamwork activity					
Individual technical work	Menu is bypassed	Management activities	Planning	Designing the product	Electronics	No one (item is automatically written in the database)	Email	Giving information
			Resolving conflicts		Mechanical/ Hardware			
			Resource assignment				Engineering software tools	Receiving information
			Negotiation		Software			
		Evaluation activities	Analysis/Simulation	Designing the process	Manufacturing/ Deploying		Office software tools	
			Decision making					Processing information
			FMEA		Logistics/Installation		ERP	
			Measurement/Testing		Maintenance/Servicing		PDM/PLM	
			Monitoring/Reviewing		Disposal/Reusing		Internet	Exchanging information
		Definition activities	Conceptual./Design		People/Team members			
			Detailing/Coding				Knowledge base	
			Ideation/Improvement					Requesting information
			Documenting				Paper misc	
			Prototype realization		Facilities/Infrastructure		Logbook	
			Sales/Procurement				Calendar	Searching for information
			User support		Other individual context		Other individual technical manner	
			Other individual activity					
Individual administrative work	Menu is bypassed		Time booking		Administrative (item is automatically written in the database)	No one (item is automatically written in the database)	Email	Menu is bypassed
			Arranging meeting				Office software tools	
			Arranging travel/accomodation				ERP	
			Traveling				Internet	
			Completing expense claim				Paper misc	
							Logbook	
			Data entry				Calendar	
			Checking e-mails				Other individual admin. manner	
			Other administration					
Break	Menu is bypassed		Menu is bypassed		Menu is bypassed	Menu is bypassed	Menu is bypassed	Menu is bypassed

At the start of the self-report, the participant must select the *project* they are working on in the moment. This menu is followed by the selection of the *work type* which is either individual technical work, individual administrative work, teamwork, or break. Unless break was selected, the participants must also report the *activity type*. The types of activities derived from the work of Robinson [18] and were further developed based on the ontology of development activities [21] which provides researchers a consistent and coherent description of the interpretation of typical development activities. Completeness of activity type menu was ensured through an analysis of work activities provided by the HR department of the participating company.

For individual technical and team work, the participants must also report the *activity context*, based on a detailed classification of activities' technical context as provided in the ontology for engineering design by Ahmed and Štorga [22]. If the participant is engaged in teamwork, they must select the *party* involved. Apart from generic menu items such as customer and supplier, the menu is customized to contain the names of all team members allocated to the selected project.

Participants also need to select the *manner* in which the work is performed, ranging from communication means to computer-based tools. This menu is based on the work of Allard *et al.* [23] and McAlpine *et al.* [24]. Finally, the type of *information transaction* needs to be reported for the individual technical and team work. The types of information transaction derive from Cash [25].

Once created, the menus and the menu items were validated with the company representatives and the study participants. The menus items have been developed as highly abstract to enable applicability in different environments and different types of projects.

2.3 Development of a mobile application for work sampling

Once the work sampling method was adopted, a self-reporting mobile application had to be developed to serve as a tool for utilizing the approach. This step included both functional design and user experience design for the mobile application.

The architecture of the mobile application for work sampling has been designed to consist of the sequence of input screens with predefined menus, following Robinson's research [18] and using the analogy with the concept of a self-reporting electronic diary [26]. After work sampling application randomly emits an alarm, the user (study participant) is required to respond to application's notification which immediately redirects them to the first input screen of the application. Each input screen contains items of which one or more can be selected (based on the menu structure shown in Table 1). Such way of collecting simplifies and speeds up data entry.

Additionally, the administration interface was developed to allow customization of the work sampling sessions and real-time data access. The customization of the menu structure for particular study was done by importing contextual data, including ongoing projects and people.

2.4 Case study

The Case study was conducted in the organization which is Tier 1 development and manufacturing supplier for the automotive industry in EU. A team whose preoccupation are production ramp-up [27] and production planning and development [10] was selected for the study. Team's activities include establishment and improvement of manufacturing, logistics and procurement processes.

Two types of study preparation were performed: technical check of the application functionality and introductory workshops during which the work sampling application and the way it should be used were briefly explained. Study participants also received an application manual in which they could find instructions for using the application and thorough descriptions of each menu. Employees from the IT department were responsible for checking application's technical aspects. Researchers conducting the study were open for discussions during the work sampling period to clarify all misunderstandings. As the last step before session start, it was necessary that participants test the application for a one day period to better understand how to use it. This one day period was not included in the analysis. Once the participants got used to the data input, time required for data input significantly decreased to approximately 30 seconds per alarm.

The activities of 15 team members were sampled during 13 working days (two and a half weeks). Team members' field of expertise are as follows: 8 are from technical department, 5 from engineering sales/procurement and 2 from logistics. The sampled projects were at different phases implying different workload distribution. Alarms were randomly emitted 6-8 times per day with intervals of 30 to 90 minutes between two alarms. Such intervals were determined by a variation of stratified non-continuous random sampling [10, 28], where the working day is divided into several segments of different duration to reduce variance.

3. Results and discussion

The results are presented from several viewpoints. First is the analysis of the data collection process in terms of team members' responds to alarms. Following is the analysis of the work type and the occurrence of different types of activities. Finally, the analysis of team members' activity was coupled with the context, the manner and the nature of information transaction utilized, with a goal to obtain new insights for the sample points. Due to the limited period of 13 working days sampled in this study, the results cannot be generalized on organizational level, thus only the short-term socio-technical aspects of the project have been observed and discussed. Long-term insights and the effects of the proposed approach on the technical aspects of production development such as time, cost and quality, require conduction of longitudinal studies with a significantly longer work-sampling periods. To confirm the overall correctness and accuracy of results, a workshop with all participants was organized after the sampling session.

3.1 Data collection analysis

In total 1365 alarms were emitted during the work sampling session. Team members entered data on 1127 occasions meaning that the overall response rate was 82.6 %, which is higher than the response rate reported in Robinson's study (74.87 %) [10], but slightly lower than what was reported by Škec *et al*. for the product development context (87.9 %) [19]. This number of sample points enables detection of a task accounting for 5 % of the working time, with ± 20 % precision, and 90 % of confidence [19], according to work sampling calculations available in [11], [10]. The number of overall responds to alarms varied from 42 to 96 per each team member during the sampling session. Average number of alarms responded per team member was 75.1, indicating that the average number of alarms responded per day for individual team member was 5.78. The difference in the number of alarm responds is a result of the random number of alarms emitted for each team member (during one day) and lower response rate by some team members (Fig. 2).

To ensure that team members respond to alarms promptly, the percentage of answered alarms in the given time intervals was monitored. Fig. 3 shows the distribution of time elapsed between the moment of emitting the alarm and the moment of filling out the report for the given alarm.

In total 68.6 % of the alarms were responded in the period of first 30 minutes after alarm was emitted. Additional 10.6 % were responded in the interval from 30-60 minutes after the alarm. These response rates correspond to what has been reported in the study conducted in the product development context [19] and indicate team members' fast adaptation to the study requirements. Since team members entered data shortly after the alarm was emitted, it was possible to obtain data in real time and with less retrospective bias. Other self-reporting approaches such as interviews and surveys rely on memory to recall what was happening and in what manner [18].

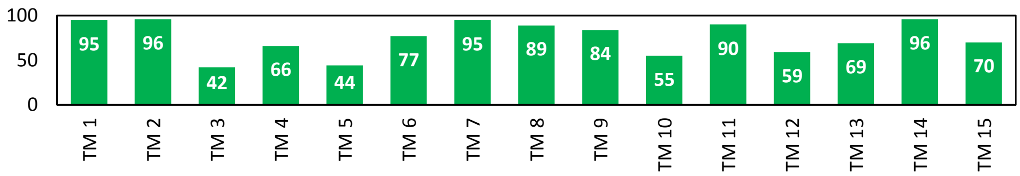

Fig. 2 Number of responds to alarms during the work sampling period for each team member (TM)

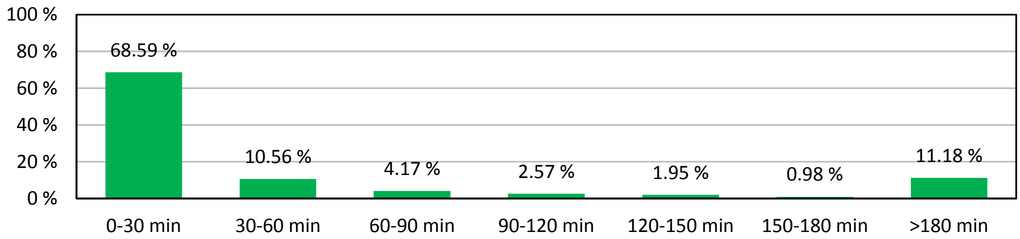

Fig. 3 Percentage of responds to alarms within particular periods of time after the alarm was emitted

Although the proposed approach allows simple data collection from team members on different locations, it still requires their additional effort as they have to input the report data. Moreover, every time team members were required to input data for a certain alarm, they were interrupted in their current execution of activity and had to again switch context from one activity (self-reporting) to another (current work activity). Because of these reasons, the motivation of team members could become an issue during long-term studies. Possible solutions could include various forms of extrinsic motivation and strong support from higher management.

3.2 Work type analysis

Analysis of work type indicated that some team members have higher proportions of *individual technical work* (e.g. Team member 6), while some have higher proportions of *teamwork* (e.g. Team member 8). One can also notice high proportion of *breaks* for certain team members such as Team member 4 (24 %) and Team member 9 (32 %) because of their absence from work during some days of the work sampling session (Fig. 4).

The results of work type analysis indicate significant proportion of *individual administrative work* among all team members. Based on the of individual work type profiles, it can be noticed that some team members were assigned more administrative tasks. Also, interviews conducted after the work sampling session showed that the reason for these results could be team members' perception of the administrative activities which were occasionally confused with routine tasks.

The proportion of teamwork activities (29.5 %) is higher than obtained in studies conducted by Škec *et al.* (14.8 %) [19] and Webster and Higgs (11.3 %) [29], but is lower than the 40.4 % of team activities in Robinson's [18] study. The proportion of team members' discussions is 18.0 % of the time, which is higher than 6.5 % obtained by Škec *et al.* [19], but again lower than the 26.3 % reported by Robinson [18]. Formal meetings have taken 18.0 % of the session time, while Robinson *et al.* [18] and Lowe *et al.* [30] reported 13.0 %, and Marsh reported 9.0 % [31]. Difference in these results arises from distinctive contexts and teams, but also due to different classification of activities proposed by the authors.

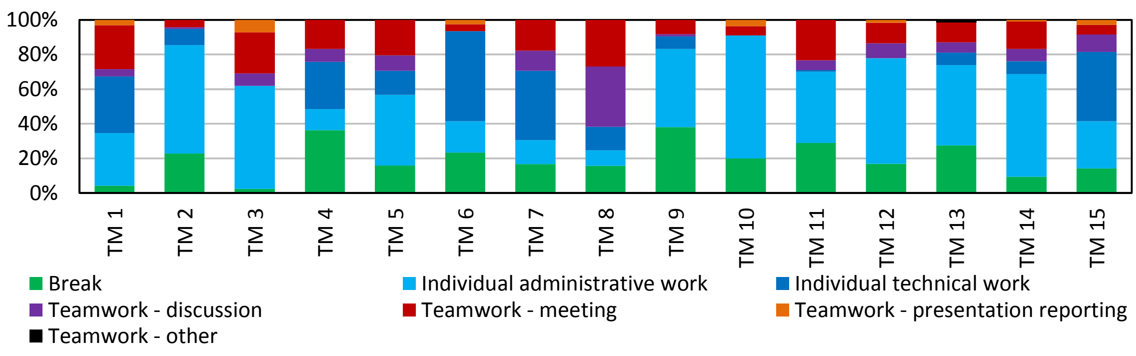

Fig. 4 Percentage of time spent in particular work type during the work sampling period for each team member

3.3 Activity type analysis

Deeper analysis of collected data was focused only on individual technical and team work activities to provide more details about the production development context. *Planning* and *sales/ procurement* activities were the most frequent teamwork activities (Table 2), followed by *resolving conflicts* and *conceptualization/design* activities, which also took significant time proportion during the session. Individual technical activities with highest time percentages were *conceptualization/design*, *planning* and *detailing/coding*. During the sampled period, neither one team member reported *ideation/improvement* or *prototypes realization* activities as part of individual work. These two types of activity also had the lowest time proportion out of all teamwork activities.

Planning as the most frequently reported activity (24.20 %) could have been anticipated in a production development team. For comparison, the study conducted in the product development context reports only 3.25 % of time spent on the *planning* activity [19]. It is important to emphasize that *innovation/improvement* activities were reported only a few times during the sampling period. Interviews with the study participants showed that they had difficulties in identifying innovations during everyday activities, which could have caused the low percentage of innovation activity. Nevertheless, the results require further analysis to identify reasons for this behaviour.

As for the context of individual work, team members mostly reported working on *transport/installation* and *manufacturing/deploying* issues. Such results were expected taking into consideration team members' professional profiles and their backgrounds. *Manufacturing/deploying* was also the most reported context during formal meetings, followed by *people/team members*. Informal discussions were again related to *manufacturing/deploying* aspect of the production development. It is possible to notice significant percentage of time spent on administrative activities as part of both individual and team work. Proportions of the time spent engaged in individual technical and team work, coupled with the production development context are presented in Table 3.

As expected, the overall proportion of *process design* activities is significantly higher than what has been reported for the product development context by Škec *et al*. [19] (22.32 % to 8.58 %), and respectively the proportion of *product design* activities is lower (8.37 % to 76.78 %). Furthermore, the time spent on issues related to *people*/*team members* is higher (5.02 % compared to 1.87 % in [19]), which can be related to a generally higher proportion of teamwork.

Table 2 Percentage of production development activities within individual technical work and teamwork

Activity type	Individual technical work (%)	Teamwork (%)	Overall (%)
Planning	16.42	30.00	24.20
Sales/procurement	7.46	15.19	11.89
Conceptualization/design	16.92	5.56	10.40
Other teamwork	-	12.59	7.22
Other individual	15.42	-	6.58
Resolving conflicts	3.98	6.67	5.52
Analysis/simulation	6.47	4.44	5.31
Documenting	8.46	2.59	5.10
FMEA	6.47	4.07	5.10
Detailing/coding	9.95	0.00	4.25
Negotiation	2.49	5.56	4.25
Decision making	1.49	4.81	3.40
User support	1.49	3.33	2.55
Resource assignment	1.00	1.85	1.49
Monitoring/testing	0.50	1.48	1.06
Measurement/testing	1.49	0.74	1.06
Innovation/improvement	0.00	0.74	0.42
Prototypes realization	0.00	0.37	0.21

Table 3 Percentage of the activities conducted in particular context

Production development context		Teamwork					Individ. work (%)	Overall (%)
		Discussion (%)	Meeting (%)	Present./ Report. (%)	Other (%)	Overall (%)		
Designing the product	Electronics	0.22	0.33	-	-	0.56	0.45	1.00
	Mechanical/Hardware	0.45	1.90	0.11	-	2.46	1.56	4.02
	Software	0.33	1.12	-	-	1.45	1.90	3.35
Designing the process	Disposal/Reusing	-	-	0.11	-	0.11		0.11
	Maintenance/Servicing	0.89	0.45	-	-	1.34	0.56	1.90
	Manufacturing/Deploying	2.90	3.35	0.22	-	6.47	4.02	10.49
	Transport/Installation	1.00	1.12	0.11	-	2.23	7.59	9.82
People/Team members		1.12	3.24	0.22	-	4.58	0.45	5.02
Facilities/Infrastructure		0.22	0.67	0.11	-	1.00	0.22	1.23
Administrative		1.23	2.12	0.45	-	3.79	48.33	52.12
Other		1.45	3.68	0.22	0.11	5.47	5.47	10.94
Overall		9.82	17.97	1.56	0.11	29.46	70.54	100.00

3.4 Analysis of activity in a particular manner

Individual technical work and teamwork were conducted in various manners and using different resources during the work sampling period (Table 4). Individual technical work was mostly conducted using the *office software*, *engineering software* and *email*. On the other hand, during teamwork, team members mostly re-ported the use of *face-to-face communication*, *telephone* and *email*.

Extensive use of office software can be explained with a high proportion of administrative work, while engineering software is required for conducting the core production development activities. Robinson reported in his study that half of the activities were carried out using computer tools [18]. Within the individual work context, the presented results are similar. And while in the product development context [19] most of individual work was carried out in engineering software tools, in production development the office software tools are dominant.

Similar as reported in [25] and [19], team activities were mostly carried out face-to-face. This manner of communication is expected for collocated teams. On several occasions (e.g. [32], [33]), researchers emphasized importance of email communication in engineering context. However, within the presented study and similar to Škec *et al.* [19] emails were used rarely as part of teamwork because of the team collocation.

Table 4 Percentage of the activities conducted in particular manner

Manner	Individual technical work (%)	Teamwork (%)	Overall (%)
Face-to-face	-	84.39	48.40
Office software tools	43.50	1.49	19.40
Engineering software tools	22.50	0.00	9.59
Email	18.00	2.23	8.96
Telephone	-	7.81	4.48
Other manner - solo technical	7.50	-	3.20
ERP	3.00	0.37	1.49
Internet	2.00	0.00	0.85
Whiteboard/Smartboard	-	1.49	0.85
Calendar	1.50	-	0.64
Video conference	-	1.12	0.64
Other manner - team	-	1.12	0.64
Knowledge base	1.00	0.00	0.43
Paper misc.	1.00	0.00	0.43

3.5 Analysis of information transaction

As a part of individual technical work, team members reported *information processing* as the primary type of information transaction. Second most frequent information transaction activity was *giving information* (unidirectional). During teamwork team members mostly spent time on *information exchange* (bidirectional) and *information processing* (group thinking) (Fig. 5).

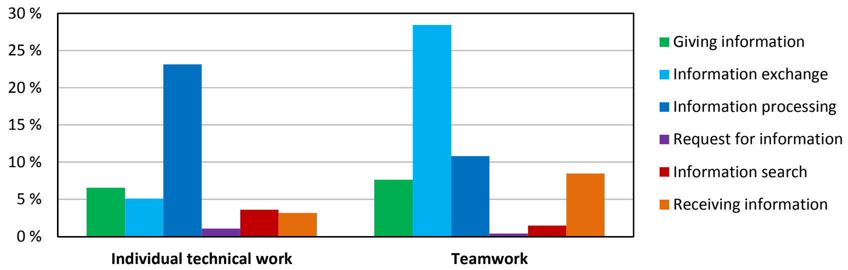

Fig. 5 Percentage of activities with a particular type of information transaction

The proportions of time that team members spent engaged in different type of activities within individual technical and teamwork in combination with the type of information transaction happening within the particular activity, are shown in Table 5.

The proportion of *receiving information* transactions was highest during *evaluation* activities (*analysis/simulation*) as part of individual technical work, and during *planning* as part of teamwork. *Information processing* in individual technical work is mostly present during *definition* activities (*conceptualization/design* and *detailing/coding*), while in teamwork this is the case during the *management* activities (*planning*). *Information search* is intensive during *"other" individual technical work*, while *requesting information* was reported for only 1.49 % of individual technical and team work during the sampling session. *Information exchange* had a significantly important role during teamwork activities such as *sales/procurement*, *resolving conflicts* and *planning*.

Table 5 Work type versus information transaction nature of activities

Activity type		Giving info. (%)	Info. exchange (%)	Info. process. (%)	Request. info (%)	Info. search (%)	Receiving info (%)	Overall (%)
Teamwork		7.64	28.45	10.83	0.42	1.49	8.49	57.32
Evaluation activities	Analysis/Simulation	-	1.91	0.21	-	-	0.42	2.55
	Decision making	0.42	1.27	-	-	-	1.06	2.76
	FMEA	0.42	1.27	0.21	-	-	0.42	2.34
	Measurement/Testing	-	0.42	-	-	-	-	0.42
	Monitoring/Testing	-	0.42	-	-	-	0.42	0.85
Definition activities	Conceptualization/Design	0.21	1.06	1.27	0.21	-	0.42	3.18
	Detailing/Coding	-	-	0.42	-	-	-	0.42
	Documenting	0.21	0.85	0.21	-	-	0.21	1.49
Manag. activities	Planning	2.76	7.43	5.10	0.21	0.21	1.49	17.20
	Resolving conflicts	0.21	2.34	0.21	-	-	1.06	3.82
	Resource assignment	-	0.42	0.21	-	0.21	0.21	1.06
	Negotiation	0.64	1.49	0.85	-	0.21	-	3.18
Other	Prototypes realization	0.21	-	-	-	-	-	0.21
	Sale/Procurement	1.27	4.46	1.91	-	0.21	0.85	8.70
	User support	0.21	1.70	-	-	-	-	1.91
	Other teamwork	1.06	3.40	0.21	-	0.64	1.91	7.22
Individual technical work		6.58	5.10	23.14	1.06	3.61	3.18	42.68
Evaluation activities	Analysis/Simulation	0.21	-	1.91	-	-	0.64	2.76
	Decision making	0.21	0.21	0.21	-	-	-	0.64
	FMEA	-	0.21	1.49	-	0.64	0.42	2.76
	Measurement/Testing	-	0.21	0.42	-	-	-	0.64
	Monitoring/Testing	0.21	-	-	-	-	-	0.21
Definition activities	Conceptualization/Design	1.06	0.21	5.73	-	-	0.21	7.22
	Detailing/Coding	0.21	-	4.03	-	-	-	4.25
	Documenting	0.42	0.64	2.12	-	0.21	0.21	3.61
Manag. activities	Planning	1.91	2.12	2.12	0.21	0.21	0.42	7.01
	Resolving conflicts	0.21	0.85	0.64	-	-	-	1.70
	Resource assignment	-	-	0.21	-	-	0.21	0.42
	Negotiation	-	0.42	0.21	-	0.21	0.21	1.06
Other	Sale/Procurement	0.64	0.21	1.49	0.42	0.21	0.21	3.18
	User support	0.42	-	0.21	-	-	-	0.64
	Other individual	1.06	-	2.34	0.42	2.12	0.64	6.58
Grand total		14.23	33.55	33.97	1.49	5.10	11.68	100.00

4. Conclusions and future directions

In here presented study, a self-reporting work sampling approach was used to observe the activity of individuals and teams in production development context. Work sampling approach in form of a mobile phone application provides new opportunities for collecting self-reporting data. In comparison to wearable recording equipment and tracking software [9], work sampling application requires less data coding which leads to better understanding and interpretation of collected data. This is of great importance for research studies conducted in real organizational settings, since data interpretation is context-dependent and relies on the project manager's expertise.

The study reveals specific aspects of individual and team activity in production development, such as context, content, type and manner. Analysis and interpretation of the obtained data provide added value to project managers in form of insights into the activity of development teams, including resources they use and how they collaborate. By combining different facets of knowledge about the development activities, project managers can tailor workloads of team members and modify team composition to improve collaboration, coordination and information exchange. Moreover, the use of the self-reporting approach can eliminate the need for employees to compile daily, weekly or monthly work reports, thus reducing time spent on administrative work and improving satisfaction. These benefits suggest that implementing the approach can correspond to the introduction of organizational and administrative innovation in the company [6].

The proposed approach doesn't require researchers to be present at the workplace during the data collection procedure, since there is no need for individual observation of each team member. Such less intrusive approach is a perquisite to conduct data collection in the real organizational settings. However, the approach requires a significant amount of preparation efforts, such as menu creation, application distribution and installation, and introductory workshops. Regardless of researchers' absence, the proposed approach as such still has significant biases since the approach is based on self-reporting. Team members are prone to entry biased data to appear "better" than the others [34]. For that reason, it is important to emphasize the purpose of the study in the introductory workshops to decrease animosity towards this type of studies. Bias could be also caused by emotional state of each team member during the session intervals.

Using the proposed methodology for longitudinal studies, it is possible to compare activity execution by different development teams and/or organizations. Such insights could be used to understand working routines and to modify existing practices related to team composition, resource planning, knowledge needs, and activity execution. Project managers could also use the data to determine project archetypes and adjust their management accordingly. For routine projects, the insights can reveal possible deviations from previously managed projects. The causes for these deviations could be identified via multi-perspective data collection approach, in which the work sampling insights can be coupled with other methods, e.g. PFMEA [35]. Furthermore, longitudinal studies can reveal the long-term effects that the proposed approach has on production development, such as the influence on development costs and efficiency. Further research will include tailoring of the proposed methodology for understanding of project health in terms of the socio-technical aspects, and identification of the production development risks on organizational level.

Acknowledgement

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

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