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Rule Base for Operative Planning and Control of Flexible Labour Hours

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Abstract: Within this paper the core components of a cyber-physical-system (CPS) for the support of a self-organised and highly flexible labour utilisation will be presented. It displays the on-going German research project "KapaflexCy" within the CPS will be developed. Further the possibilities and impacts of a flexible labour utilisation will be researched in three case studies. The approach of the project is to involve employees in the personnel planning and scheduling. The core components of the CPS are a matching and voting board for mobile communication devices, a central planning and scheduling instance and a rule base with a comprehensive set of priority and eligibility rules for work assignments. The rules are guiding the process of matching and voting for work assignments. They limit the possible work assignments within a legal and economical justified corridor for flexible working hours. The paper will highlight in particular the rule base of the CPS to be developed within the project.

Keywords: Task allocation-sharing and job design, Human operator support, Human supervisory control.

1. INTRODUCTION

The influences to the actual production quantity and workload of manufacturing companies are manifold. Product lifecycles, the world-wide economic activity, seasonal demands, marketing campaigns, or overlaid, very large, singular orders in combination with the globalisation of the markets and upcoming international competitors make it difficult to estimate the actual workload for a specific period (Tolio 2001). It especially seems to be impossible to predict the world-wide economic activity reliably (Bullinger 2009). As a consequence manufacturing companies cannot predict and plan their production quantity and workload in advance.

Nevertheless they have to meet high requirements in terms of short delivery times, low stock quantities and competitive costs (Salvedy 2001, Hopp 2008). They have to fulfil customer demands for products of high quality faster and more reliably as the competitors (Spath 2008). The still used approach of a centralized planning and scheduling of production demands and orders (Aritiba 1996) is too slow and to inefficient to meet new requirements of dynamic and volatile markets. Therefore companies are forced to utilise flexible forms of production activities, schedules, and labour (Oechsler 2011). In a current survey of the Fraunhofer IAO 72% of the participating companies agreed, that they need to increase their possibilities of flexible labour utilisation within the next five years (Spath 2013) (Fig 1).

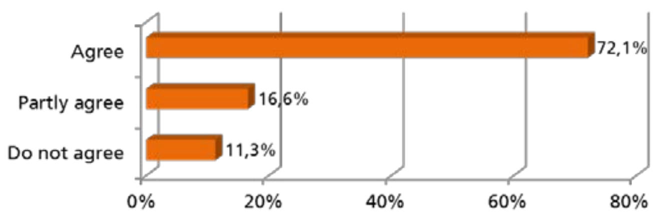

Fig. 1. Demand for Flexibility (Spath 2013).

Especially in countries with high wages, companies have to maintain their business responsiveness. As a key element, flexible labour utilisation has to reflect the short-time fulfilment of individualised customer demands in real-time as well as the fluctuations of volatile markets. The personnel planning therefore have to stress divergent targets in terms of reliability and productivity. Criteria for the assignment of working hours to employees are, among others, the current work load or the necessary qualification for work assignments. Moreover the personnel planning have to meet long term strategies for the responsiveness and flexible adjustment of human resource allocation. Criteria are among other the total or periodical amount of overtime hours or the share of part time workers. And at least, the personnel planning have to reflect the individual requirements and personal concerns of the employees. Obviously the personnel planning and scheduling is a complex task of several stakeholders with divergent targets. In the survey mentioned above, 62% of the participating companies stated, that their effort for short-time production control is high (Fig 2).

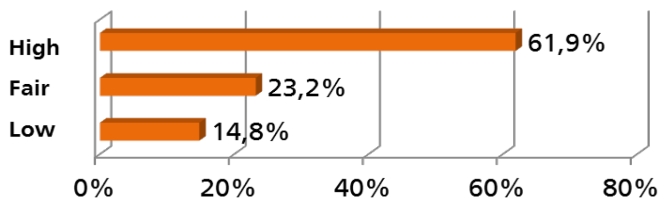

Fig. 2. Effort for short-time production control (Spath 2013).

The approach of the project “KapaflexCy” is to involve the employees in the personnel planning and scheduling of their work assignments. It is expected, that the results of the project will increase the degree of flexibility of labour utilisation in production. The companies will be able to react efficiently, immediately and in short times to unbalanced and fluctuating workloads. Thus they will be better prepared for volatile markets. At the same time they can reduce the effort for their capacity management. For employees it is expected, that they will be involved in the process of the personnel planning and scheduling. Groups of employees use mobile communication devices together with social media functions to agree upon their work assignments. Thus they will experience a transparent personnel planning and they can better combine the concerns of business demands with their private and leisure interests.

The core of the research approach of the project is a so called Cyber-physical-system (CPS). The application of CPS in production environments is a new research topic in Germany. The impacts are expected as so tremendous, that they will be designated as the ‘4th industrial revolution’ (Forschungs-union 2012). To stimulate this important future vision, the German government has started a large national research program in 2012. Three ‘early bird’ projects have to investigate and establish the recent field of research. KapaflexCy is one of them. The main task of the German research project ‘KapaflexCy’ is the development of strategies, methods, and tools to implement, support, and operate a self-organised scheduling of labour times (Gerlach 2012).

Within the following paper, the application of CPS in production environments will be introduced. Afterwards the approach and preconditions of a self-organised labour utilisation will be explained. The 4th chapter gives an overview of the core components of a supporting CPS. One of the core components, the rule base will be explained in detail in the 5th chapter. It will be concluded by a preview of the research activities.

2. CYBER PHYSICAL PRODUCTION SYSTEMS

Cyber-physical systems connect the virtual cyber world with the real, physical world to an Internet of things, data and services (Uckelmann 2011). They capture data of the real “physical” world via sensors, process them with software from embedded controllers, use the Internet and cloud computing for mutual communication between the connectors and interact with real world by means of mechatronic actuators (Lee 2008, NSF 2011). First application fields include e.g. robotics, car navigation, health care or energy distribution (acatech 2011). The application of CPS for production processes will be regarded as a new key technology, which will be called Cyber-physical production systems (CPPS) within this paper. To remain successful, it will be crucial to develop and operate autonomous, self-managing, knowledge-based and sensor-based production systems (Forschungsunion 2012).

The list of possible applications of CPPS in the industrial production is manifold. Mobile and real-time assistance systems with context-sensitive user interfaces control and monitor production processes constantly. Self-organising and networked production equipment detects and configures their components and tools. Decentralised local memories in production equipment or products collect, store, review and distribute detailed information about the product and production processes. More Examples are given in (Broy 2010, Glotzbach 2009, Geisberger 2012). It is expected, that CPPS will shift production technology, processes and equipment towards flexibility and self-control of the production facilities. The desired benefits are evident. Intelligent, networked objects and autonomous control systems are able to reflect customer demands in real-time. The flexible utilisation of production facilities with short throughput-times and zero-stock are the answer to the increasing demand of customised products and the trend of more volatile markets. Therefore a paradigm shift is expected, from centralised production planning to a decentralised coordination of self-controlled and autonomous processes.

Figure 3 shows a sketch of the CPPS to be developed within the project KapaflexCy. The “pysical” components to be controlled with this CPPS are flexible labour hours and work assignments. Therefore the actuators are employees which are using mobile equipment with specific user interfaces. The assignment of working hours will be coordinated by the control component. The core of this component is the rule base as described in chapter 5. The control component interacts with similar CPPS in the “Cyber-World”. Typically CPPS have to share data with the existing Enterprise Planning Systems (ERP). Therefore an interface to the “Business Systems” will be needed.

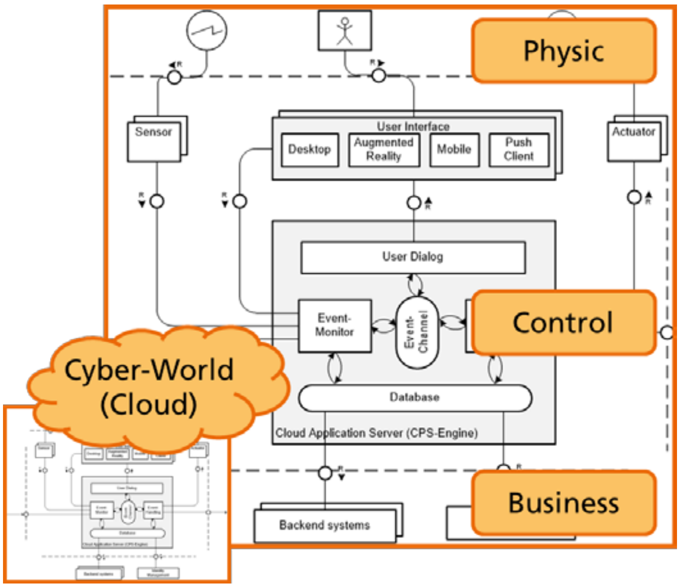

Fig. 3. Basic Elements of a CPPS.

3. FLEXIBLE LABOUR PLANNING

As introduced in the first chapter, volatile markets demand flexibility. CPPS and the paradigm shift towards decentralised coordination and autonomous processes are a proposed technical measure to meet the flexibility demand. CPPS will give a significant boost to flexible labour. Together they implement a self-organised labour utilisation to be described throughout this chapter.

3.1 Flexibility Instruments

Labour utilisation has to follow the facility utilisation closely. Daily working hours must not longer be on fixed times and equally spread throughout the day. They still have to reflect the fulfilment of customer demands in real-time.

There are two principle ways for flexible labour utilisation in general. First, the working time of a group of employees can be reduced or enlarged, perhaps day by day. Second, the group of employees can be reduced or enlarged. Figure 4 gives an impression for the two ways by the example of a so called "U-Shape assembly system". Within this system one worker can assemble a whole product by passing all work places in one walking circle. According to German law he is allowed to work at maximum ten hours a day in Germany. There is no law for the minimum working time. But usually there is a minimum amount for the daily working hours because of economically reasons. If a higher utilisation is needed, an additional worker may be added to the assembly system. The two workers split the assembly tasks between them. Obviously the maximum amount for workers within the assembly system is given by the number of work places.

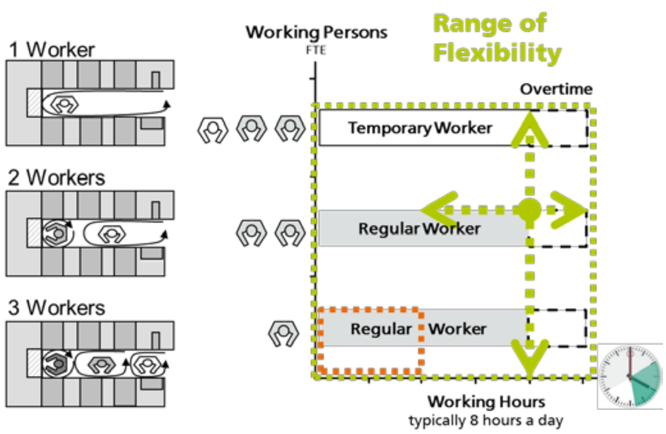

Fig. 4. Flexible Working Hours.

An overview and brief introduction of the common measures to implement a flexible labour utilisation is given e.g. in (Reilly 2001). These measures will often and throughout this paper be called 'flexibility instruments'.

3.2 Manual Scheduling of Work Assignments

A flexible labour utilisation requires a short-term control of flexibility instruments and the use of staff. In practice this is done always manually. Team leaders and shift managers coordinate the arrival and absence of staff, requesting support by part-timers and freelancers and plan the use of temporary workers. For this purpose they communicate daily with their workers, the human resources department, additional shift managers and temporary employment agencies - usually orally, rarely, and with sufficient time by E-Mail. This kind of short-term staff usage is also reactive. Occurring capacity gaps have to be closed by daily trouble shooting, in which usually established patterns will be used. That denotes, that always the same flexibility instruments are used and the same staff will be requested. A coordinated use of flexibility instruments in regard to volatile markets is hardly possible.

The manual and oral coordination of flexible capacity utilisation and the use of short-term staff are therefore subject to serious drawbacks (Witte 2003). First a high coordination overhead due to oral communication, second short-term adjustments of capacity use does not succeed, third an uneven distribution of lucrative or unlikely activities, and fourth a false and cost-driving use of flexibility instruments.

3.3 Self-Organised Labour Planning

In a self-organised labour planning, horizontal decisions within and between working groups will replace the conventional vertical directives 'from top to bottom'. A central coordination instance and mobile devices provide a platform for employees to agree self-organised upon their work assignments. They have to decide, which persons take over the additional work assignments. The use of mobile devices accelerates the assignment process between employees who are more accessible in this manner. Moreover they ease the horizontal oral communication between the employees, which may be helpful in specific situations. A self-organised labour planning comprises of seven essential steps (Fig. 5), as described in the rest of this chapter.

Step 1 flexibility range. Usually a company provides a mix of different overlaid and sized flexibility instruments. The mix has to meet the unsteady demand for capacity. Further restrictions may result e.g. from long training periods or high qualifying requirements. Therefore the mix and size of the flexibility instruments has to be determined thoroughly based on a calculation of the total benefit and the financial budget needed (Hämmerle 2013).

An exemplary outcome of an instrument determination and sizing could be the selection of the instruments 'Use of temporary workers in the context of 0-10% of the core workforce' as well as 'Use of flextime from - 200 h to + 200 h per employee'.

Step 2 flextime direction. It has to be decided, which flexibility instruments should be used preferably for a specific period of time. Two general flextime directions will exist: Reduce or increase flextime records of core employees.

For example, if a company has a particular seasonal demand, it is probable to need overtime in the peak season. Hence the overtime records have to be reduced in the low season. Therefore the flextime direction during low season will be "reduce" and part time workers have to be utilised instead of overtime of core employees.

Step 3 work schedule. In a particular case of capacity alignment, it has to be decided, which of the provided flexibility instruments should be used, with respect to the flextime direction. Usually the production supervisor is in charge to align the working hours to the actual workload. For this he plans and schedules additional shifts or he cancel already scheduled shifts.

Step 5 matching and voting. The group of eligible employees will be informed about possible work assignments, which are scheduled from the supervisor. A request message is send to their mobile devices via the communication platform. They can agree and vote upon their work assignments directly over their mobile devices, as shown in the next section.

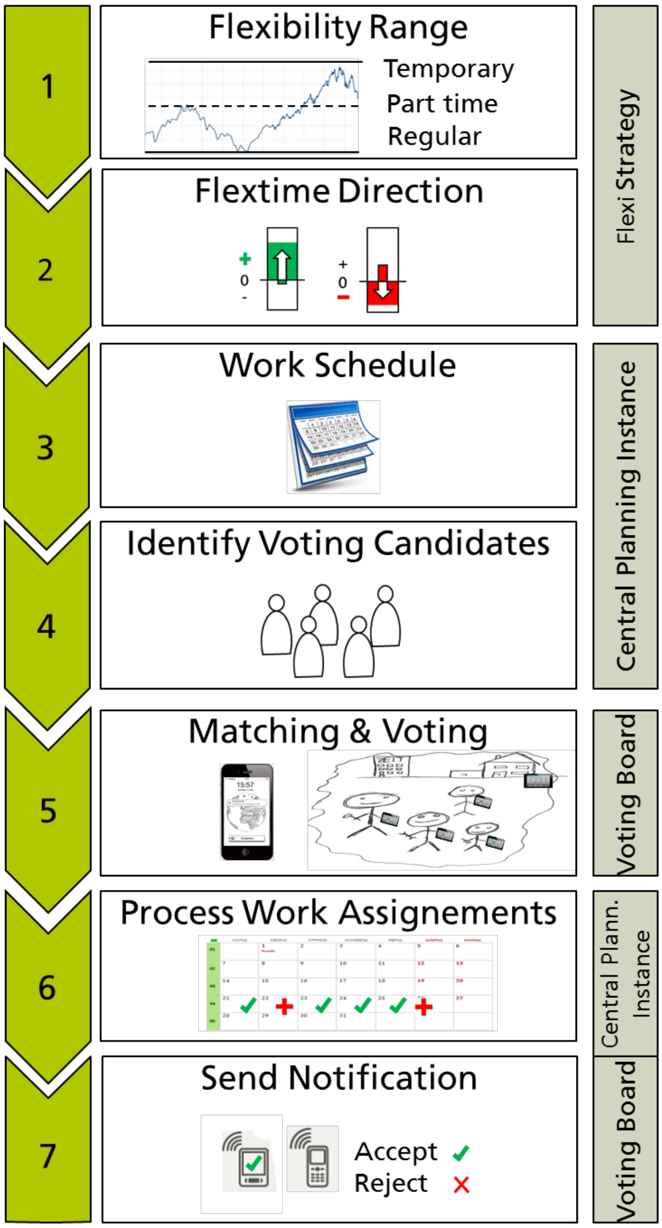

Fig. 5. Process of self-organised labour planning.

Step 6 process work assignments. After the employees have voted upon their work assignments, the supervisor will be informed about this. He can fix the assignments and close the voting requests. The schedule of work assignments will be updated.

Step 7 send notification. An informational message about the fixed work assignment is sent to the employees to close the process formally.

4. CORE COMPONENTS

The last chapter describes the organisational and logical aspects of the concept of a self-organised labour utilisation. This chapter gives a brief introduction of the core components of the CPPS, to be developed within this project.

The first core component is a **mobile matching and voting board** for the employees. A mobile push client will inform the user immediately about events and new possible work assignments he has to vote for. The push client may use typical means to attract attention. For example the telephone rings or the smartphone vibrates. He has the role of the actuator in the CPS.

Figure 6 shows the mock-ups of the user interface of the voting board. The screen at the left side is the mock-ups for the request message. Information about the possible work assignment is given. For example an additional shift is scheduled for Saturday and employees with qualification of adjusting and transporting are eligible. The employee can agree to the work assignment or he can reject it via the action buttons in the upper right corner of the screen. The voting is displayed in the screen at the right side.

The second core component is a **central planning instance** which comprises of different cockpits for order backlogs, actual workloads and shift schedules with work assignments. The component is mainly operated by the production supervisor which also monitors the matching and selection processes of the employees.

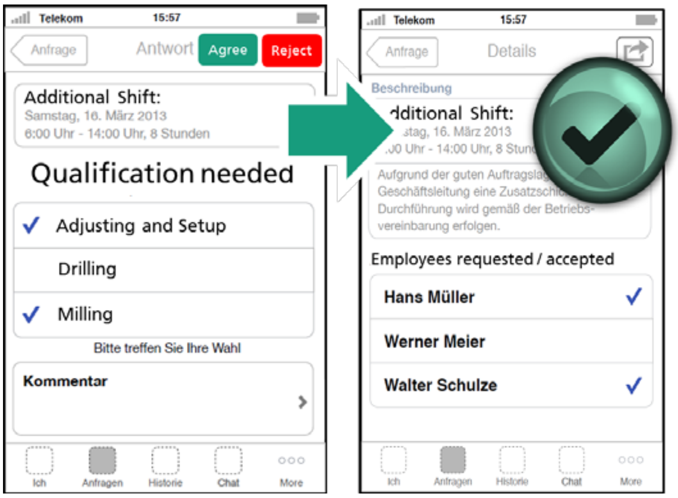

Fig. 6. Sketches of the mobile voting board.

The third core component is a **rule base** with a comprehensive set of priority and eligibility rules for work assignments. The eligibility and priority rules have to be adapted, customized, and trained to the business environment and market behaviour of the company, which uses the CPPS for flexible labour utilisation. Thus they will be implemented as explicit formulated rules which will be processed by an dedicated rule engine. This offers strong means to adapt the CPS to individual business environments.

5. RULE BASE

The rule base is primarily intended to support the steps four and six of a self-organised labour planning, since there is no general behaviour or algorithm for them. The identification of candidates to vote upon work assignment depends on several stakeholders with a variety of criteria and four basic groups of requirements as described below (Fig. 7).

First the employees have to be identified which are eligible for a work assignment. The basic question is about employees, which **can work**. Usually this is a question of qualification and training of the employees with respect to the working equipment and the production task of the work assignment. Unskilled or untrained employees will be eliminated from the voting group.

For the rest of the members of the voting group it has to be checked that they meet all legal requirements or which one **must not work**. For example, a employee in Germany is not allowed to work more than 10 hours a day. Therefore it makes no sense, to ask him for an additional morning shift, if he already is scheduled for the night shift the day before. Also his weekly working hours have to be less than 50 hours and the pause between two work assignments has to be 11 hours at minimum. There are some more legal requirements which may be governmental rules or agreements between the management and the staff of a company. So the legal requirements change over time and they are varying between companies.

Now all eligible candidates are identified. Nevertheless there are distinguished priorities for the employees to take over a work assignment. Priority rules calculates which employees **may work** preferably. For this, they compare the flextime direction with the flextime wage records against the conditions of the working contract of the employee and calculate a priority figure for each candidate.

At least there are personal priority rules of employees who **want to work.** They are addressing personal preferences, exclusion periods for applications or relationships between employees. For example two employees always want to work at the same time since they share one car to come to work.

With this four groups of rules it is possible, to identify the employees which will be asked to vote upon a work assignment on their mobile matching and voting boards, see Step 5 in Figure 5.

After voting a **final decision** will be drawn about accepted work assignments in Step 6 which is again guided by the rule base. Usually the step of matching and voting upon work assignments needs some time. Also it may be the case that the same employees are voting upon several work assignments in parallel. Therefore it has to be rechecked, that the employees are still eligible for the work assignments.

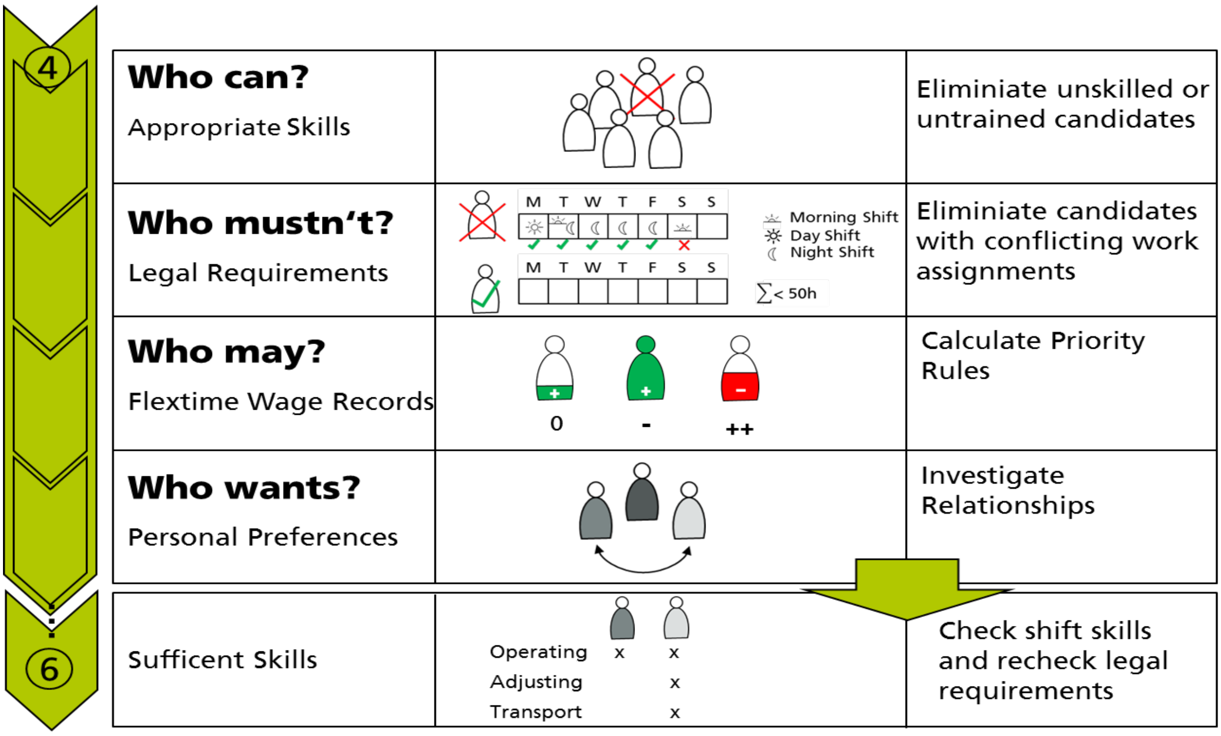

Fig. 7. Process of self-organised labour planning.

Moreover the priority of the employees will be recalculated in case of multiple applications for work assignments. Usually the work will be assigned to the employee with the highest priority that has voted for the assignment. At least it has to be checked, that all the needed qualifications for the shift are covered by the assigned employees.

6. CONCLUSIONS

At the moment a prototype of the rule base will be implemented and tested. The open source Tool “Drooles” will be used as an development environment. At the end of the project, three pilot applications of developed tools and methods are planned by the industrial application partners in the project. The pilot applications will gain valuable insights about conditions, requirements, and acceptance of the developed tools, and about the economic benefits of a self-organizing labour utilization. Also the pilot applications will prove the applicability of the rule base. The tool will only be accepted, if the rule base can identify appropriate voting candidates.

If the expectations in this form of highly flexible work come true, the findings could be transferred to content and spatially distributed work. New forms of work identity and employment could emerge in an industry 4.0, which includes the membership of an employee to several teams and employers in a 'Multi-job employment'. Especially in a urban context of production a highly flexible 'PatchWork'-employment may be possible.

6. ACKNOWLEDGMENT

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More information about the ongoing research project is provided via the website http://www.kapaflexcy.de. Please apologize, that the website is in German language.

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