Chapter 3

Multi-agent based simulation in supporting the working time management

Rational time management remains one of the still poorly appreciated factors influencing the increase of management efficiency. Time defines the essence and range of changes, including changes/transformations in the economic area, affects social and economic development and influences the quantity of produced goods and services. One may say that time is a regulator of economic and social mechanisms.

3.1. Introduction

If the frame of reference, in view of which time of a certain phenomenon or process is defined, is work, and more precisely changes occurring during the working process, then the quantitative aspect of this movement will be working time. It consists of this share of activities used by a person which appears mostly in the process of production and the provision of services. Working time is inextricably linked to work – it is the condition of its existence and its form of being [K92].

Growing competition in multiple dimensions and areas, including first and foremost the spread of internationalisation and globalisation, has caused the fact that some companies started to look for new ways to achieve competitive advantage. Time based competition has become one of them (the term "time based competition" was coined by Boston Consulting Group – BCG) and it consists mainly in practical application of time compression of basic manufacturing processes, especially taking into consideration production process and sales process. This time based competition has recently become a general development strategy for many companies [KP09].

Even a cursory glance at scientific publications allows one to notice that the question of time management covers a wide scientific range. Its individual issues are analysed from the point of view of various scientific disciplines. The majority of those issues concern macroeconomic problems, while others are examined in the micro scale, i.e. individual economic entities. In this article the wide scientific range has been narrowed down to the analysis of issues relating to working time management of workers in a company. The article presents an example of how

multi-agent based simulation is used to support working time management. The chapter briefly characterises multi-agent based simulation and defines the concept of an agent and its basic properties. A concept of a simulation model for working time management in a company is also presented.

3.2. The specificity of working time management

Nowadays, in times of the pursuit of profit and efficient action, the need to use modern, process-based and holistic methods of working time managements in companies is increasingly clear. Market dynamics make companies analyse their market position and, in consequence, draft plans of adapting to new market conditions, such as changing strategy, restructuring, modifying their products or services and introducing new ones, reducing production time and other processes which may affect making profits. The general trend is that those changes are to be implemented instantaneously or at least faster than before. Therefore Time Based Management (TBM) is becoming an increasingly popular practice. It is a modern management concept based on time, whose basis is the effective use of time in a company (e.g. in order to develop new products and launch them faster, to increase profit, etc.). Hence time is key value here, around which the whole system of managing processes in a company and its prospective results is built.

In practice, time-oriented organisation means that the attention of people responsible for proper implementation of company strategy (supervisors on any level of the organisation) will be concentrated on smooth processes, on carrying out tasks and, what is also important, on developing high-quality cooperation between particular departments of a company and even between individual employees. This is, among other factors, why effective company management requires defining clear and unambiguous objectives, developing functional action plans and supervising their progress. Appropriate definition of company objectives is the basis of effective working time management since: it helps to concentrate on specific tasks by particular departments of a company, allows to create long-term visions of the activities of the company, allows to make simulations of company's achievements, helps also to organise human resources by assigning tasks to individual employees and increasing their motivation to intensify their dedication to achieve common objective.

It is important to specify here how working time is defined. According to Article 128 of the Labour Code it is time when an employee remains at employer's disposal at workplace or any other place designated for performing work [U98].

The phrase that an employee remains at employer's disposal means that working time is also being ready to perform work and not only its performance at any given moment [B07]. Working time system is a set of principles connected to the organisation of working time admissible by labour law, which contains provisions concerning the norms of daily working time, weekly working time, accounting periods, etc.

In recent years one may observe more often and more clearly the opening gap between the quantity and rate of implementing technological advances and organisational changes on the one hand, and the range and rate of changes in working time system on the other. This creates an organisational gap, highly expensive for a company and economy. The widening of the gap becomes an ever bigger problem for Polish companies and institutions and its elimination – a significant scientific issue.

The starting point for indentifying and analysing the system of working time management in a company may be the general term of the management system of an organisation (e.g. company, institution). Management system means the entirety of measures, persons and practical actions referring to organisation's management and skills, regulating norms and formal or informal rules connected with it [KP09]. On this basis one may build a model of a working time management system, which may subsequently be expanded and specified for the purposes of particular companies (see fig. 1).

To summarise, proper working time management is key resource, crucial to the functioning of each company, institution or organisation. Precise definition of objectives, applying methods and rules of time management, identification and elimination of the so-called time-killers and systematic supervision allows for its effective use.

3.3. General characteristics of multi-agent based simulation

Computer simulation is a method with a wide range of application in multiple fields of science. This method consists in creating a simulation model of an object or system in the form of mathematical and logical notation and presenting relationships describing the simulated object or real system and its environment in such a way that these relationships may be studied by changing the input signals and model parameters. Computer simulation is a method of reproducing phenomena of the real world with the use of their mathematicised models defined and operated with the use of computer programmes [MPK13].

Multi-agent based simulation (MABS) is one of the simulation techniques which has gained a lot of popularity in recent years as a method of supporting decision-making. Until the early 2000s, agent based modelling was pretty much an academic topic. The adoption of agent-based modelling by simulation practitioners started in 2002-2003 [B13]. Agent-based models are created in order to solve problems in many areas, including company management [S11]. Each contemporary company has to manage communication and information exchange with their clients, suppliers and employees, needs to manage its assets and plans, and also ensure control over the circulation of internal information concerning their offered products and/or services. In each of these actions MABS may prove helpful. This article describes the application of MABS to support working-time management.

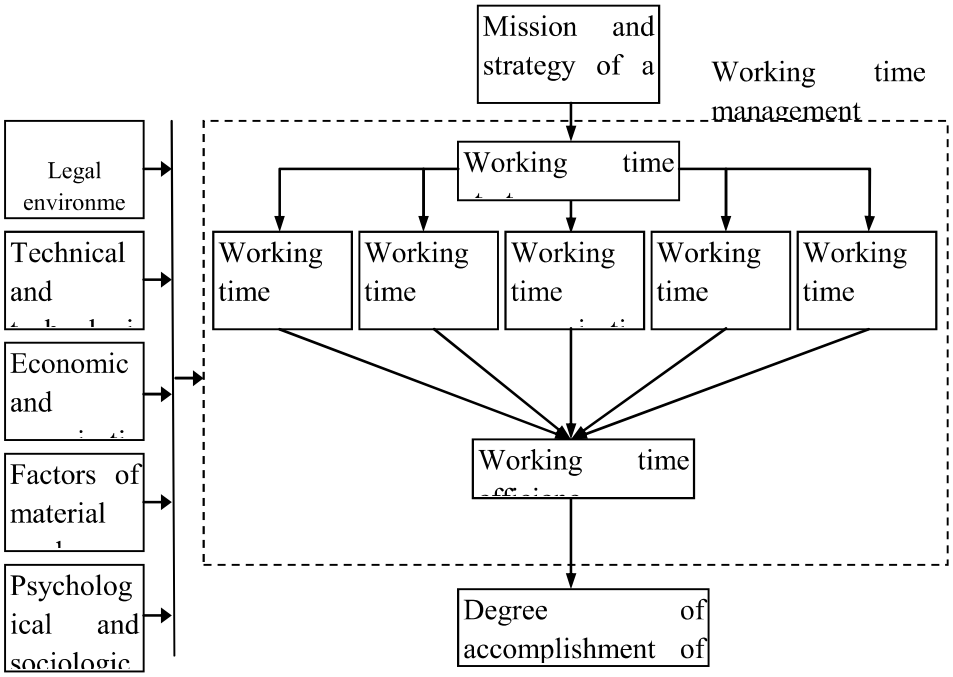

Figure 1. A model for working time management in a company

Source: author's own elaboration based on [KP09], p. 345345.

In MABS the studied system is modelled as a set of autonomous units, called agents (the notion of agent and its basic characteristics will be defined in the next passage). In a multi-agent model, decision-making processes in micro-scale are

described for each agent individually. An image of a studied phenomenon in macro-scale results from connecting actions of multiple agents and their interactions with one another [SA08]. The use of MABS means that a certain modelling procedure is observed (for a full description of a multi-agent modelling procedure see [ŁWWF12]). It starts with formulating the problem and setting out the objective. The next step is to define the simulation environment in the studied area (including, most of all, agents, space and environment) and to specify the system borders. The next step of the procedure is connected with the issue of obtaining input data for the model. For the person conducting the study it is a key stage as an incorrect choice of the method of gathering information may prevent them from meeting the objectives of the study. Then, on the basis of data gathered, one may start constructing multi-agent based model of the analysed system. The starting point in conducting MABSs is the initialisation of a certain population of agents. It consists is defining the attribute values of agents (their internal states), rules of behaviour and the principles of communication between them. The next stage of multi-agent based modelling procedure is carrying out the computer simulation, i.e. starting the simulation model. The results of a simulation (so-called base course), illustrating the behaviour of a studied system in time, are compared with the available data on the system and the model is verified, if need be. The model is verified as long as it satisfactorily reflects the real behaviour of the system. The next stage of the procedure at hand is the simulation of effects of potential changes in agents' behaviours (including simulation experiments). Then the results of the base course are compared with results of experimental courses, and analysis and assessment of simulation results is made (statistics methods are most frequently applied for this task). The last step of the procedure is formulating conclusions of the study.

In the past few years there has been a considerable development of multi-agent based modelling and simulation software. Simulation packages have become more complex and universal. Currently the market offers various simulation programmes, starting with the simplest, based on mathematical models (e.g. NetLogo, Repast) and ending with the most developed, with stochastic system allowing to adapt input data to the right distribution, with an environment for creating animations, 3D images, multiple tools for presenting the output of a simulation (e.g. AnyLogic).

3.4. Characteristics of agents

In 1980s the notion of an agent began to take shape, as well as a certain set of its characteristics. However, it is still difficult to find in academic papers a generally accepted, universal definition of an agent. Wooldridge and Jennings define agent as a computer system situated in an environment and capable of operating autonomously to perform their actions, necessary to achieve their goals [B06] [WJ95]. Figure 2 presents an abstract agent model in which the agent observes its environment and generates actions shaping this environment.

Many articles present various descriptions of what characteristics should an agent have. For example, typical characteristics of an agent compiled by Franklin and Graesser [FG96] are presented in table 1.

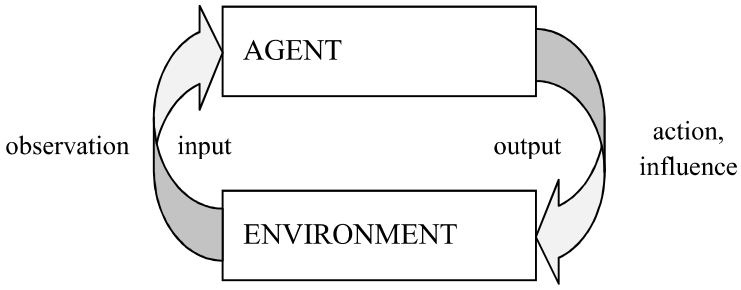

Figure 2. Agent and its environment

Source: Author's own elaboration on the basis of [B06], p. 13 and [W02], p. 16.

To summarise, one may assume that an agent has the following characteristics [MN06]: (1) it is an identifiable unit with a set of certain characteristics and principles governing its behaviour and decision-making abilities; (2) it is situated in an environment in which it interacts with other agents; (3) its action may be goal-oriented; (4) it is autonomous, may function independently in its environment and in contacts with other agents, at least in certain predefined situations; (5) it is flexible, has the ability to learn and adapt.

Table 1. Typical characteristics of agents

Property	Other name	Meaning
Reactivity	Feeling and action	Reacting to changes in the environment
Autonomy	-	Control over their actions
Goal orientation	Proactivity	Not simply acting in response to their environment
Continuity	— -	Continuous process
Communicativeness	Social ability	Interacting with other agents and also humans
Learning, mobility, flexibility	Adaptability	Adaptive changes in behaviour based on previous experience, ability to move, action based on personality and emotions, and not on scripts

Source: [D10], p. 353.

One should underscore here that agents in simulation models may represent various objects: vehicles, items of equipment, designs, products, ideas, organisations, investments, people in various roles (e.g. consumers, suppliers, employees), etc. [B13] The next section of the article describes an example of how MABS can be used to support the working-time management, in which agents represent employees of a company.

3.5. A concept of simulation model for managing working-time in a company

Assuming the general model of working-time management system in a multi-dimensional approach as the starting point, one may develop a simulation model which will be created and detailed for the purposes of a particular company. For the purposes of the study it has been assumed that a hypothetical company offers its services consisting in renting equipment, machines, scaffolding and cranes for construction industry. It employs a permanent working force (50 employees), qualified both to install and to repair the machines. Devices are installed and repaired with intensity proportional to the number of employees delegated to installations and repairs. The management of the company tries to delegate as many employees as possible for installation works to clients (as it generates profit for the company). Delegating employees to do repairs happens when a machine failure occurs – the intensity is proportional to the number of broken machines. The repair takes place in the seat of the company and lasts some time (2 hours on

average), after which employees return to installation works, which are the priority of the company.

Service system consists of a team of technicians who begin their daily work in company's office and then leave for their clients, according to the list of commissions. In their work they use company's IT system which has a separate Service module. This Service covers the control of all actions, connected with providing technical service for machinery rented by the clients. It allows registering all performed installations with their technical descriptions, the activities of technicians, performing technical review and repairs, monitoring financial settlements, registering and analysing costs. Thanks to cooperation with this module, technicians may be up-to-date with commissions entered into the system and accept them for realisation. Thanks to the access to the system via the Internet, after an installation is finished at client's place, each of the technicians may check what other commissions are queued and, depending on the situation, go to another client (perform an installation of a rented machine) or, in case there are no installation commissions, return to the office (to attend to potential repairs).

In the proposed MABS model, each of the 50 employees is an agent. Agent's behaviour is relatively simple: receiving a commission, ride to the client, installation of the machine, return to the company and carrying out next commission or repairing a malfunctioning machine. This can be illustrated by five states in which an agent can be: *Waiting*, *Ride to the client*, *Installing*, *Return to the company*, *Repair*. Transition between these states is dependent on certain occurrences. Transition from *Waiting* depends on the occurrence of a failure. If there is no failure, a technician receives an order to provide an installation service at client's place – i.e. the agent transitions from *Waiting* to *Ride to the client* and then is in the *Installing* state. Once the installation is finished, the technician comes back to the office – i.e. transitions to the *Return to the company* state and again enters the *Waiting* state. If, however, a failure occurs, the technician remains in the company's office and engages in repairing the machine – i.e. the agent transitions to the *Repairing* state, and after the repair is finished – again to *Waiting* (see fig. 3).

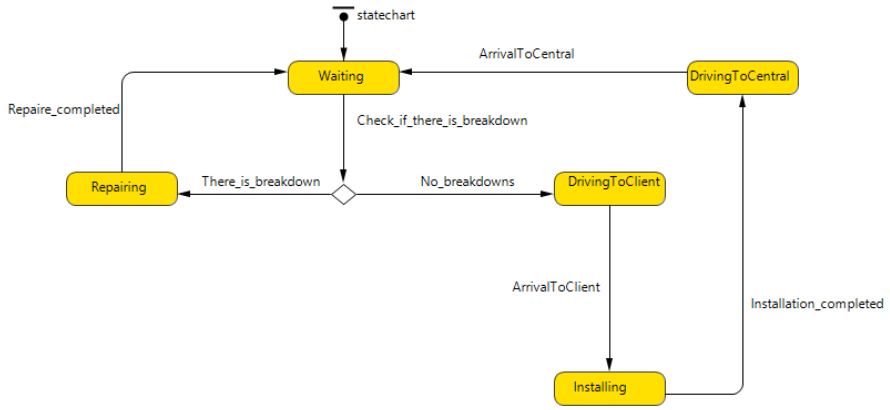

Figure 3. Main diagram of the states of employees

Source: author's own elaboration.

As mentioned above, one of the key characteristics of agents is their ability to communicate. In the model at hand this aspect has also been included. All instances of communication between agents and other objects may be divided into four types:

- technician's arrival at the client's: a message sent from an agent to the client,
- completion of installation: a message sent from an agent to the IT system of the company,
- completion of repair: a message sent from an agent to the IT system of the company,
- checking whether any failures occurs: message from the "central dispatcher" (here: the IT system of the company) to all agents-technicians.

In the analysed simulation model the environment of an agent may be described as two-dimensional space 100 km by 100 km. Therefore we assume that each agent can service a client within 100 km from company's office (if it is located in the centre of this area). Because of necessary simplifications, the model does not include roads, the only assumption is that agents travel in straight lines in all directions within the radius of 100 km during an 8-hour working day and the mean speed is 60 km/h (fig. 4).

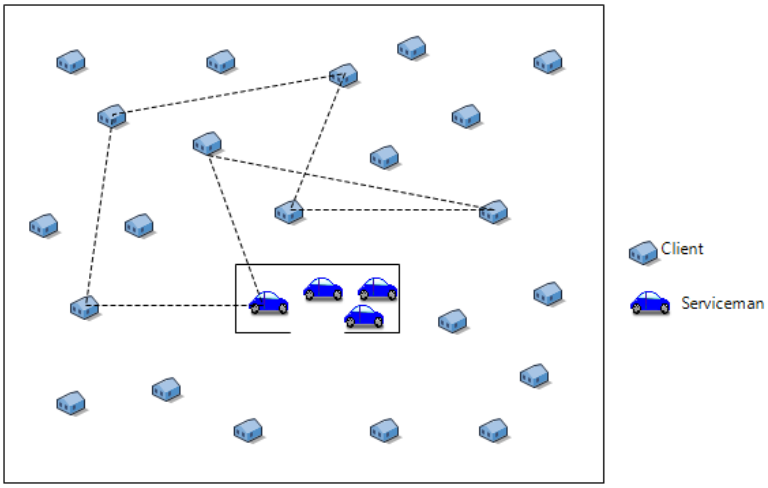

Figure 4. The space of a simulation model for working-time management

Source: author's own elaboration.

According to the adopted multi-agent based modelling procedure, the next stage was conducting a computer simulation, i.e. launching simulation model (due to the breadth of the subject in the article, the description of technical details connected to constructing a multi-agent based model in AnyLogic system was omitted). The results of the simulation were subsequently statistically analysed and on the basis of this analysis, charts illustrating evolution of certain phenomena in time were generated. For instance, Figure 5 presents simulation results for 6 weeks. The stacked chart shows the number of employees engaged in performing basic activities connected to work, i.e. installing machines and devices at client's (*Installing*), repairing broken machines and devices (*Repairing*) and waiting for another commission (*Waiting*).

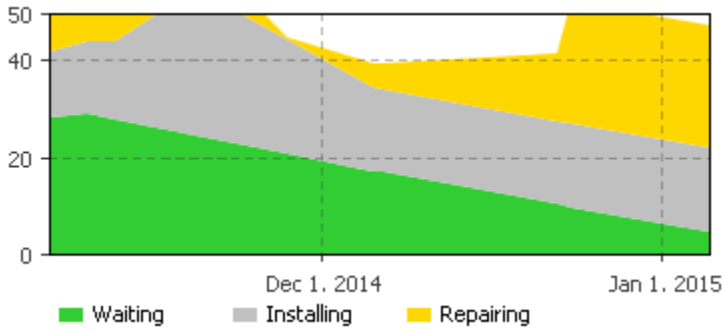

Figure 5. The engagement of employees in performing basic tasks (time of simulation: 6 weeks), Source: author's own elaboration.

3.6. Conclusion

The article presents an example of how multi-agent based simulation may support working-time management. A concept of a simulation model has been described, pointing to its main aspects and their respective determinants. While creating it, both strategic and operative approaches have been taken into consideration. Strategic approach to working-time management means here a situation whereby a company aims at connecting working time with its strategic objectives, thanks to which it becomes an important tool supporting the process of the adaptation of the company to the changes in market and consequently increasing the competitiveness of the company.

Thanks to the ideas presented in the article one may draw the conclusion that MABS is a method which may be and is used successfully to support working-time management. One may conduct a virtually unlimited number of experiments in a short time using the simulation model built according to the proposed procedure with an appropriate simulation package (e.g. AnyLogic, Swarm, NetLogo); this allows to examine the influence of many factors on effective working-time management of employees of a given company.

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