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Modeling and simulation of bus assembling process using DES/ABS approach

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KEYWORD

Agent based modeling; simulation; assembling; production plant.

ABSTRACT

This paper presents the results of the project, which goal is to analyze the production process capability after reengineering the assembly process due to expansion of a bus production plant. The verification of the designed work organization for the new configuration of workstations on new production hall is necessary. To solve these problems authors propose a method based on mixing DES (Discrete Event Simulation) and ABS (Agent Based Simulation) approach. DES is using to model the main process – material flow (buses), ABS is using to model assembling operations of teams of workers.

One of obtained goal is to build a simulation model, which presents the new assembly line in the factory, taking into ac-count the arrangement of workstations and work teams in the new production hall as well as the transport between workstations. Second goal is to present work organization of work teams and division of individual workers' labor (who belongs to a particular work team and performs operations on buses in a particular workstation) in order to determine the best allocation of tasks and the optimum size of individual work teams. Proposed solution enables to determine the effect of assembly interferences on the work of particular work teams and the efficiency of the whole production system, to define the efficiency of the designed assembly lines and proposing changes aimed at the quality improvement of the created conception.

1. Introduction

The authors of the article are conducting research in a bus production plant. Due to the increasing number of orders and the diversity of bus types, the assembly organization which has been applied so far does no longer meet the new requirements. Therefore, the reorganization of the assembly process is necessary. The factory employees have a radical idea for changing the organization of the assembly process. Their idea is to transition from one assembly line to three parallel assembly lines. As a result, such a change can be considered as the reengineering of the assembly process (Hammer et al., 2003).

The main goals, which the enterprise wants to achieve, are the elimination of «bottle necks» and the increase in the production process efficiency. In the reengineering project the company staff designed the arrangement of workstations in the new production hall and the work organization of work teams, which perform various operations for many different types of buses. Then the simulation model was made to verify the described concept. The scope of the project includes:

- building a simulation model, which presents the new assembly line in the factory, taking into account the arrangement of workstations and work teams in the new production hall as well as the transport between workstations,
- presenting work organization of work teams and division of individual workers' labor (who belongs to a particular work team and performs operations on buses in a particular workstation) in order to determine the best allocation of tasks and the optimum size of individual work teams,
- determining the effect of assembly interferences on the work of particular work teams and the efficiency of the whole production system,
- defining the efficiency of the designed assembly lines and proposing changes aimed at the quality improvement of the created conception.

The problem, which we need to analyze simultaneously, is the question of verifying the efficiency of the designed workstations' system, especially when the factory produces such types of buses which are the most labor-intensive for employees.

In the course of research and creation of the simulation model there are a lot of difficulties. They are mostly related with the need to understand the specific vision of the company's employees, as well as with the visualization and verification of the new work organization and the appropriate use of data about operations in the simulation model. After the selection of data, there is the creation of separate lists of operations for each work team. These lists are determining, among other things, sequences and execution times of operations for different types of buses. The lists of operations are organized in a such way that operations are carried out in accordance with the technological route (used in the factory) and the actual state of affairs in the production plant. A big challenge is to present the work organization of various work teams in individual workstations.

The model is created with the use of LogABS (Agent Base Simulation for Logistics) technology (Pawlewski, 2015) and FlexSim Simulation Software.

The main goal of the paper is to present a method based on mixing DES (Discrete Event Simulation) and ABS (Agent Based Simulation) approach where DES is used to model the main process – material flow (buses) and ABS is used to model assembling operations of teams of workers.

The main contribution of the paper is to demonstrate use of standard task executers objects available in DES environment as the roots to creation agents and base to implement methods specific to agent base thinking.

The article consists of 6 sections. The first section provides an introduction. Some interesting papers focused on assembling of buses, trains, aircraft's and methods used for analyzing and optimization, which were published over the last few years are discussed in section 2. The third section defines the problem of new bus assembling process. The fourth section discusses the DES and ABS approaches. Implementation of Agent Base Simulation, structure of agents and communication between them are described in section five. Conclusions and plans for further work are the subject of the sixth section.

2. The literature background

The problem described in the previous section refers to balancing the production line. It is a technique applied in factories which use production lines or group technologies by elaborate objective systems (Bozarth et al., 2012). It depends on assigning work to workstations, which are connected in a series, while we should focus on minimizing the number of workstations and reduce the total idle time for all workstations, e.g. changeovers, unplanned maintenance activities (Jasiulewicz-Kaczmarek et al., 2011) for a given level of production (Cox, Blackstone, 2002). In theory, when all workstations have the same amount of work which must be done, the production line is perfectly balanced. In reality, however, most of production lines are unbalanced, because the actual amount of work assigned to individual workstations is different. The problem of proper balance of production lines is one of the most common issues raised by engineers – production organizers. It is a multi-step decision-making process, which is related to allocation of a specific permissible group of operations to workstations on an assembly line, at particular discrete points in time called the assembly cycles. Due to the criterion of optimization, the problem concerns two types of tasks: minimizing the quantity of assembly positions with a constant cycle, or minimizing the duration of the production cycle with a constant quantity of workstations. According to the classical method of balancing the production line for a set cycle time, tasks should be assigned to workstations in such a way so that the time losses (idle time of machines) are as short as possible (Bartkowiak et al., 2014). The balance problem is related to a much wider group of production lines. However, taking the constraints into account, the solution in each case is supposed to minimize the idleness of workstations. The applied methods can be classified into two groups (Scholl, Becker, 2003):

- exact methods, discrete linear programming, dynamic programming, division and restrictions,
- heuristic methods, serialization and division algorithms, approximation methods (one and many heuristics, relapse, limited time to obtain an optimal solution).

The examples of heuristic methods are as follows (Zemczak, 2013):

- RPW- Ranked Positional Weight,
- RRPW- Reversed Ranked Positional Weight,
- Kilbridge's and Wester's,
- Hoffman's Sequence Array Method,
- IUFF- Immediate Update First Fit.

In the industrial environment, the most commonly used solutions are the very simple ones. Employees create graphs on boards, in the form of magnetic panels or sheets (the size of a sheet is proportional to the time it takes to perform an individual activity), which show Gantt charts. In this case, Excel Spreadsheets are the most commonly used IT support. Usually, such solutions are sufficient to organize work in one workstation for several work teams.

However, simple solutions like, for example, magnetic boards with Gantt charts cannot solve complex problems and take into account uncertain execution times of operations which are extremely important in this case (usually execution times are changeable, they oscillates around particular values). It is also necessary to take into account the distance travelled by workers during the passing between several workstations - it is important factor in case of the assembly of large objects such buses. Considering issues listed above we decided to use simulation technology for modeling work organization of work teams. The available simulation software allows building complex models (Beaverstock et al., 2011) in a relatively easy way. Moreover many simulation programs offers tools, which supports the preparation of schedules.

The most commonly used software is DES (Discrete Event System). DES has been the main way for the process simulation of manufacturing and logistics for about four decades. This is adequate for problems that consist of queuing simulations and a variability is represented through stochastic distributions (Siebers et al., 2010). This approach is applicable in simulating the manufacturing and supply chain processes. DES models are characterized by a process oriented approach (the focus is on modeling the system in detail, not the entities) (Korytkowski et al., 2016). They are based on a top-down modeling approach and have one thread of control (centralized). They contain passive entities (i.e. something is done to the entities while they move through the system) and intelligence (e.g. decision making) is modeled as part of the system. In DES, queues are the crucial element, a flow of entities through a system is defined, macro behavior is modeled and input distributions are often based on collected, measured and objective data.

In case of assembling operations we think that the process approach is insufficient, because workers are task executers. It means that they have the list of tasks to complete. The worker decides what he will do next, based on this list. It causes, that we think about worker as an agent. To do it we use approach based on ABS (Agent Based Systems). ABS modeling seems to be useful for modeling operators and forklifts, which have their own «intelligence», where the intelligence means the ability to complete changeable task lists (in this case – the picking list). An operator must have the ability to receive and send messages, to the adoption of a task list, and to send a message about the execution or termination of the implementation of the task list. In the literature this approach is also referred to as Task Driven (Beaverstock et al., 2011).

Many authors try to mix approaches. Below is a discussion of some interesting papers focused on assembling of buses, trains, aircraft's and methods used for analyzing and optimization, which were published over the last few years.

The work (Vrba et al., 2015) describes the Airbus A350 assembly line organized as a sequence of several assembly stations. A solution is presented for scheduling the aircraft production during the ramp-up phase. The developed scheduler features a combination of multi-agent systems and classical constraint logic programming algorithms. The concept of multi-agent systems is used to break down the complexity of the scheduling problem into smaller, independent sub-problems that can be solved independently and in parallel by individual agents.

The purpose of the study (Pechoucek et al., 2002) is to introduce, customize and exploit the multi-agent production planning technology (ProPlanT multi-agent system research prototype) in two specific industrial enterprises. An agent-driven service negotiations and decision process, based on usage centered knowledge about task requirements, substitutes the traditional production planning activity. ExPlanTech multi-agent planning and scheduling system is deployed in Skoda Auto engine assembling workshop. It is an example of multi-agent system approach applied in production planning software development.

In the paper (Li Da Xu et al., 2012) an integrated assembly planning system AutoAssem is introduced. The systems components are structured as follows: Assembly Modeling, Assembly Sequence Planning, Path Planning, Process Planning and Visualization, Assembly Simulation. AutoAssem has provided a comprehensive solution for a higher level of automation in assembly planning of complex products. Digital assembly is based on Object-oriented method.

The paper (Di Gironimo et al., 2009) deals with the manufacturing process of a railway carriage. In the first part of the paper, the authors focus on a «virtual railway factory» that uses a very innovative assembly cycle, if compared to the traditional manufacturing processes in the railway field. The second part of the paper deals with the simulation of the assembling operations and the analysis of tolerance chains, which have been performed through a Computer Aided Tolerancing system.

Very interesting study of small bus manufacturing company is presented in (Yazgan et al., 2011). There have 17 assembly stations and they produce 8 buses per day in the assembly line. The chosen product had 53 jobs description and total processing time equals 3,966.40 min. The jobs assigned to assembly stations are performing according precedence relations among themselves. On any assembly station, having completed all the jobs necessary, the semi-finished product is carrying to a next assembly station to be perform for remaining jobs. The assembly station time equals to the longest processing time of a worker and the takt time is the longest time among 17 assembly stations' time. They use analytical method, heuristics algorithm with multi-response Taguchi method.

The study (Jayaprakash et al., 2015) focus on mixed-model assembly line sequencing which includes determination of a production sequence for multiple products along a single assembly line. The objective of the study is to maximize percentage of utilization and minimize makespan to improve productivity in an assembly line. In this paper, four different methods of line sequencing are considered. Discrete event simulation software (Pro-Model) is used to model the assembly line operation setup and evaluate the best sequence.

The paper (Angelidis et al., 2012) explores solution approaches for scheduling problems in complex assembly lines in industrial environments. Researches focuses on small series or even unique items such as turbines, planes or industrial machines. It is unclear if they use agent approach in this simulation model. Yet the present approach seems compliant with the theory of self-organization and object-oriented modeling usually found in ABM. The scheduling of such complex assembly lines is a large combinatorial optimization problem and is often mentioned in the literature as a Multi-Mode Resource-Constrained Multi-Project Scheduling Problem (MMRCMPSP).

The application of intelligent agent technologies is the main subject of (Merdan et al., 2013). Multi-Agent System simulation is deployed to optimize the total system output (e.g., number of finished products) for recovery from the machine and/or conveyor failure cases. Diverse types of failure classes (conveyor and machine failures), as well as duration of failures, which are used to test a range of dispatching rules in combination with the All Rerouting re-scheduling policy. This paper proposes to revise and re-optimize the dynamic system schedule in response to unexpected events.

The paper (Chandra et al., 2014) is an attempt to get solution using optimization techniques using linear programming problem (LPP) or heuristics. Then simulate those sets on Petri Nets. The Petri Net is an interactive, simple and also very powerful technique to show the problem graphically and code the same using general purpose programming language for validating the same for intended result.

In (Zhang et al., 2013) a special flexible job shop scheduling problem is presented. The problem has continuous-operation constraints at the last stages. The simulation and the genetic algorithm are combined to solve the problem. The processing paths of all jobs are decision variables and they are designed to be individual in the genetic algorithm. The simulation with the reverse process flows evaluates the feasibility and fitness values of individuals.

The paper (Fortino et al., 2013) presents an emerging research area: the integration of agent-oriented software engineering (AOSE) and agent-based modeling and simulation (ABMS). This integration can offer novel validation tools that can deal more effectively with the design and validation of large-scale agent systems, before they are implemented and deployed. Authors are describing the hybrid simulation modeling and simulation-based optimization (SbO) for solving job scheduling problems. The classical deterministic job shop operations are modeled as a discrete-event simulation model - AnyLogic 6.9 is used for DES model.

The paper (Kuchař et al., 2016) describes a method developed through the use of simulation for dynamical allocation of human resources based on their competencies. Human resource capability and productivity influences the duration and allocation of resources to activities in the process. Different allocation strategies are based on this capability and productivity model to determine which resources should be allocated during automatic simulations. BPM/DES approach is used. The model is called the Coordination model and it specifies the behavior of the process as a sequence of activities. Flows in the Coordination model are enabled by multiple activity scenarios and concurrency of the activities can also be modeled using special modeling techniques.

The example used in the paper (Huang et al., 2016) is designed for HTM. The company operates a light-rail transport network in The Hague. Authors use methodology AMG Automated Model Generation. The goal is to develop a method to automatically generate simulation models.

„Msassembly» program is invented by the authors (Suszyński et al., 2015) on the basis of an algorithm for determining assembly sequence for parts and machinery sets. The algorithm is based on hypergraphs and directed graphs, as well as on assessment of transitions between assembly states. «Msassembly» supports determination of assembly sequence using directed: hypergraph and graph, state matrix and Dijkstra's algorithm.

The study (Adham et al., 2014) develops a new dynamic sequencing method to improve activities on the assembly line and also an automated sequence-control system. Hybrid model (HM) combines Multi-Objectives models, Genetic algorithm and Simulation Model. Arena Simulation Software is used for DES approach and Matlab – dynamic systems.

The aim of the work (Savino et al., 2012) is to propose an approach dealing with a dynamic management of a job shop production system featured with re-entrant job possibilities. The production shop floor is structured with a Multi Agent System (MAS) able to front dynamically these type of events. In this paper a MAS model is applied for the job shop scheduling in a dynamic manufacturing system with the problem of re-entrant job, in order to give to the system the possibility to react to the events occurring in the real scenario.

Authors based on their researches propose to mix DES and ABS approaches. In next sections we explain our thinking.

3. Bus Assembling Process

Described project is being performed in one of the biggest bus production plants in Poland. In recent years the number of contracts won by the company is steadily growing and their products are conquering the European market. Due to the rapid development of the company there is a need for investment in expansion of the production area, new organization of processes and modern technologies. The topic of the project is the analysis of assembly process efficiency after its reengineering in an expanded production hall. The reason of reengineering process is insufficient performance of assembly line. The current work organization does not allow to takes full advantage of labor force and it is impossible to realize the necessary number of procurement's. Imperfections of the current work organization are becoming a problem for the company employees and directly affects financial results of the company.

Currently, work is performed spontaneously, based on the knowledge and experience of the foremen. Data about the time and sequence of performing operations are not standardized. Employees are often not able to perform all operations in one cycle of work. Workers perform them in the next workstation or continue operations when other work teams have already finished working on a bus. The consequences of these actions are overtime work and disruptions in work execution. A serious problem is uneven division of tasks. The potential of many workers is not used in the right way, while others are overworked. That is why, the company management have decided to expand the production plant by building a new production area and changing current work organization. The purpose of these actions is to improve work efficiency, reduce the time and distance traveled by workers during the assembly process and, therefore, help the company save both time and money.

The defined task is to visualize and verify designed work organization on expanded production hall, so that the design of precise arrangement of workstations and work teams is necessary. The aim of the analysis performed with the simulation model is to confirm or reject the new organization of the assembling process and identify imperfections of the created conception. These activities will help the company to improve the project before it is put into practice and also avoid time-consuming and expensive verification or solving problems which may appear.

The model presents group of workstations called: ST0, ST1, ST2, ST3, ST4, ST5, ST6. These workstations support three parallel production lines (Fig. 1).

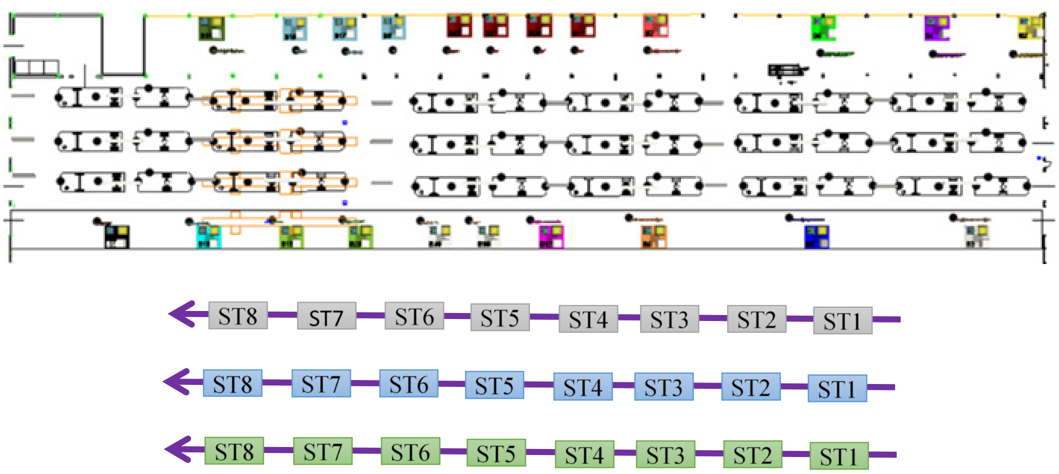

Figure 1: Material flow by three parallel production lines

The main change is to transition from a single assembly line to three parallel assembly lines, which work with certain delay relative to each other, but their work is synchronized. This is a complex problem because it is necessary to describe each phase of the process, which involves completion of more than 2700 operations by over 200 workers, in accordance with particular technological routes, dedicated for many types of buses, which are located in 20 workstations. Six major zones are designated in each workstation, depending on the stage of production. These zones are the destinations for workers, who have to execute their assembling operations. The division of the workplace into zones is shown in Figure 2. Zones are marked with the numbers 1 to 6, which means respectively: 1-front, 2- interior, 3- back, 4- side, 5- roof, 6-chassis of the bus. The employees also carry out the sub assembling operations in the dedicated zone of the production hall.

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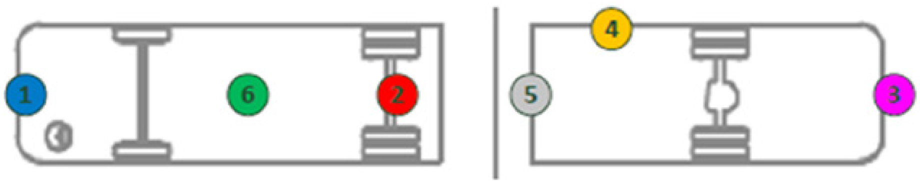

Figure 2: The division of a workplace into various zones

In addiction the workstations are supported by workers divided into many work teams, which have different names, different sizes and various lists of operations which must be performed in consecutive cycles of work. Data about individual work teams are presented in Table 1.

Table 1: Summary of the information about the work teams

Work teams name.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
The number of members.	15	12	12	11	11	11	11	13	12	10	11	12	12	14	10	13
Supported workstations	ST0	ST1	ST1	ST1	ST2	ST2	ST3	ST3	ST2, ST3, ST4	ST4, ST5	ST2, ST3, ST4	ST4	ST5	ST6	ST6	ST5, ST6

Each work team consists of a specified number of employees, which works in specific workstations. Each work team is assigned a list of operations taking into account the necessity and time of their execution for defined types of buses. B1 work team works in accordance with a specific algorithm, which is different from work organization of the other work teams. It is result of working only in ST0 workstation with no cooperation with other work teams and longer time of one cycle of work on single bus. B9, B10, B11 and B16 work teams work in many workstations at the same time. Takt time of the production line for ST0 workstation is 300 minutes, while for ST1, ST2, ST3, ST4, ST5 and ST6 workstations it is 450 minutes. After 300 minutes (which each bus spends at the ST0 workstation) or 450 minutes (in case of others workstations) a bus is moved to the next workstation within a given production line.

The ST1-ST6 workstations are supported by at least three work teams, which works continuously in a workstation for 150 minutes and then passes to the next production line within a given workstation. The way of changing workstations by B2, B3 and B4 work teams in time is shown in the figure 3.

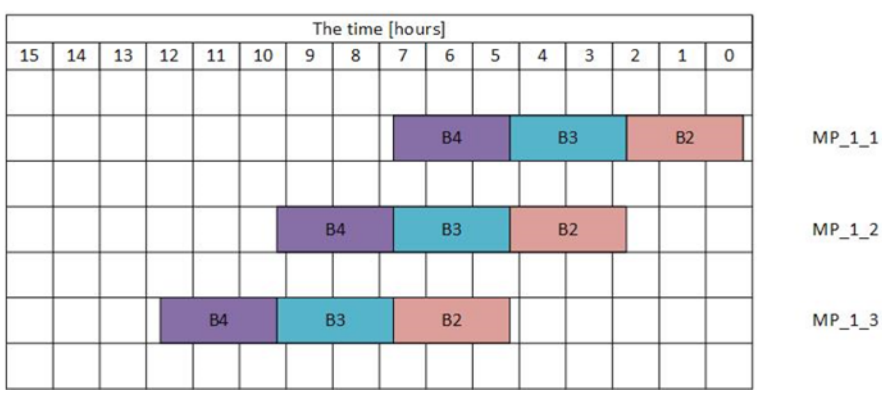

Figure 3: Work organization of a work team

Buses pass through several workstations within the same assembly line. In the consecutive workstations buses are operated by other work teams. Employees from several work teams perform operations on buses in a sequence and time defined by lists of operations in global tables. Therefore, it is possible to carry out activities in accordance with the technological route and the work reality in the factory.

The data obtained from the company:

- information about the number of staff in each work team, with their assigned workstations, supported by a several work teams,
- list of all operations carried out during the production process,
- duration of each operation, depending on the bus type,
- project of the new production hall,
- locations and names of workstations,
- layout of operator workplaces in a workstation.

The assumption of the project:

- speed of workers is 37 m/min.

4. DES/ABS approach to simulation modeling

As mentioned earlier – section 2, authors propose to mix DES and ABS approach to model work organization of work teams. Typically, simulation tools use a process driven approach where the flow of the parts between processes cause the demands on resources, i.e. a part moves to a machine and demands resources to complete the operation. Whilst this methodology is fine for some applications it does not allow for situations where the resources have tasks to complete which are not flow related – in. In these situations a task driven approach ensures that jobs can be undertaken realistic, e.g. an operator (mobile resource) has the job of performing a set of inspections of idle equipment when not otherwise engaged in process work. The task based approach allows for the creation of activities for an operator (mobile resource) which are totally independent of any processing activities and allows him to become engaged in a set of tasks which may require him to travel, acquire tools and remain «busy» for a period. Furthermore, using a task driven approach, resources can incorporate their own 'intelligence' to decide what jobs to do and when.

Many discrete event's simulation programs available on market offer these possibilities. For the performed project we choose FlexSim due to the following features (Beaverstock et al., 2011):

- ease of use in a real size with drag and drop technology,
- core 3D modeling,
- loading an .dwg file from the layout directly to a model,
- objects ASRS vehicle, Crane, Robot, Elevator,
- extended possibilities to model conveyors,
- fitting the shape of trucks and their parameters – in real values,
- integrating built-in experimenter tool with OptQuest,
- including task sequence technology.

Flexsim Simulation Software is a powerful analytical tool, which allows building three-dimensional computer models of systems as well as studying and analyzing their performance at a significantly lower cost than in case of real-time simulations. Moreover, constructed model must be easy to use and understandable for its future users, because it takes into account all their requirements for the verification of the designed process and also helps them to understand it.

The bus assembling process is characterized by this feature that the bus is moving from station to station every cycle time (450 minutes) and on the station some work teams (group of operators) must complete many tasks. Their work depend on task lists not on flow. So natural way is to model flow of buses using standard process approach (offered by DES program – in this case by FlexSim) and to model work of operators grouped in work teams using task driven approach. FlexSim offers one of more developed task driven approach on the market, but it is still not enough for complex model of human works. We need more general concept/idea, more «smarter» object which break the restrictions of FlexSim's task sequence concept. Approach based on ABS offers it. Additionally, FlexSim has (from 2015) the ability to create custom objects that are capable of simulating the underlying logic of complex business processes. Up until now, most of this customization required user to write code in FlexScript (FlexSim's internal scripting language). While many advanced users appreciate being able to tinker directly with the code, some users might prefer a simple, user-friendly interface that writes the code behind the scenes for them. The Process Flow module is designed specifically to fill these requirements.

Summarizing we conclude that in many situations in industry to model the main process DES approach is appropriate and for many (but not for all) support processes like logistics processes, work of teams of operators – the ABS approach is better and more effective – figure 4.

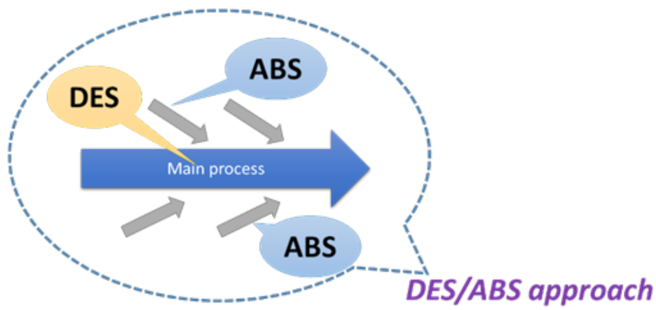

Figure 4: DES/ABS approach for modeling manufacturing processes

5. Implementation of ABS in DES environment

This section presents the main idea to implement ABS in discrete event simulation program. We prepared the solution in environment of FlexSim. This program offers the task sequence mechanism to model mobile resources. The modeler has possibilities to prepare the list of tasks for execution using special functions. The set of tasks includes following activities: travel, load, unload, break, utilize. FlexSim offers the special object called dispatcher to manage the set of operators. We extended this concept. We define agents based on task executers from FlexSim – we add intelligence it means that our agent (extended FlexSim task executer object) can make decision and he prepares based on order for him, his own list of tasks to do with possibilities to change this list. The defined agent has following characteristics according to (Macal et al., 2007):

- identifiable, a discrete individual with set of characteristics and rules governing its behaviors and decision-making capabilities,
- autonomous and self-directed,
- situated, living in environment with it interacts with other agents – has protocols for interaction with other agents,
- goal directed – having goals to achieve,
- flexible – having the ability to learn and adapt its behaviors based on experiences.

To solve problem of modeling and simulation work of many work teams for assembling, we define two special agents:

- base agent – contractor,
- team agent.

Contractor is agent build based on task executers from FlexSim, but his set of skills is extended in comparison with original task executer from FlexSim – Table 2.

Table 2: Summary of the information about the work teams

Feature	FlexSim task executer	Agent Contractor
Making decision	No	Yes
Possibility to check and evaluate the situation	No	Yes
Base skills	Travel, load, unload, utilize	Travel, load, unload, park, ready, check, check and load, call (other agent), free, reorganize, work
Where is represented intelligence?	Outside task executer	Inside - Intelligence is represented within each individual entity

Team agent is the agent which has following activities:

- to prepare the goals for agents from work team based on order (main task list) – list «Tasks» in Figure 5,
- to control – it means to select, prepare and activate agents in work team,
- to control time.

The protocols for communications between agents and team agent using list «Tasks» are defined – Fig. 5

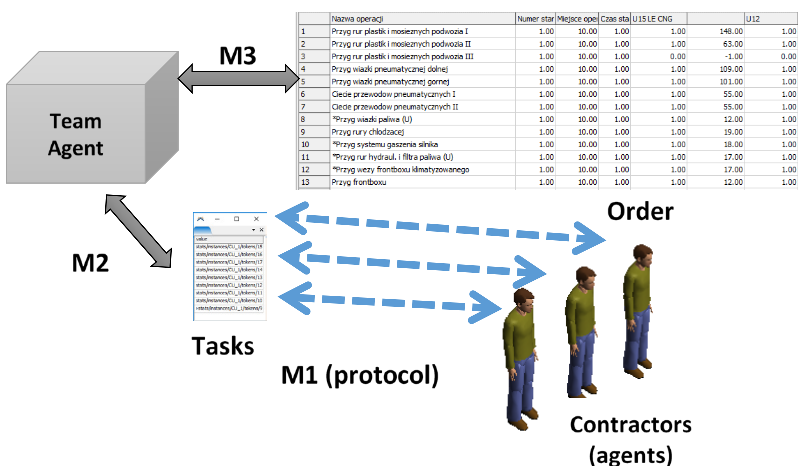

Figure 5: Information flow between agents

Orders (list of activities to perform) are built based on excel file obtained from bus company. The structure of this file is as follows:

- a row in a table – one activity from the location indicated by columns,
- columns contain the name of the activity, number of station (Fig. 1), number of zone (Fig. 2), time of activity depend on type of bus – if time is 0 it means that this activity is not valid for this type of bus.

The Team Agent prepares the list of tasks based on the set of rows from Order table (M3 arrow from Fig. 5) and publish it – «Put Task On List» instruction in Fig. 6. Publishing means that the list of tasks is ready to read, check and book by Contractors when is completed – special feature of list «Tasks» fig. 6. Contractors (agents) can obtain task to do using some methods like auction – typical for agents approach – instruction «Get Next Task» in Fig. 6. If no tasks to do – the contractor waits for task or decides to do something else.

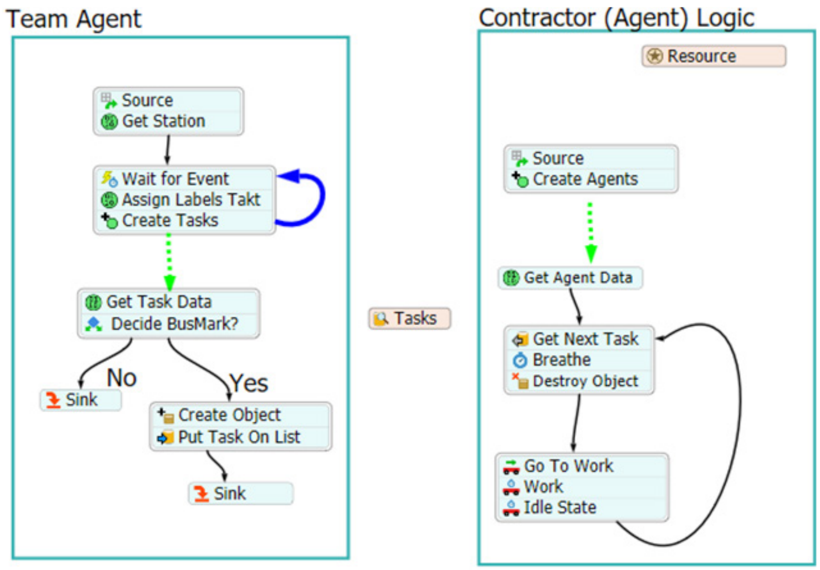

Figure 6: Team agent logic and Contractor logic

The Team Agent works as an answer to a request from the assembling line Fig. 7 – big arrows with «Requests» starting from ST1. At the moment when the bus enter to station the requests are sent to Team Agents which are assigned to this station. Team Agent has to perform the list of all activities in cycle time (150 minutes) using all Contractors assigned to team.

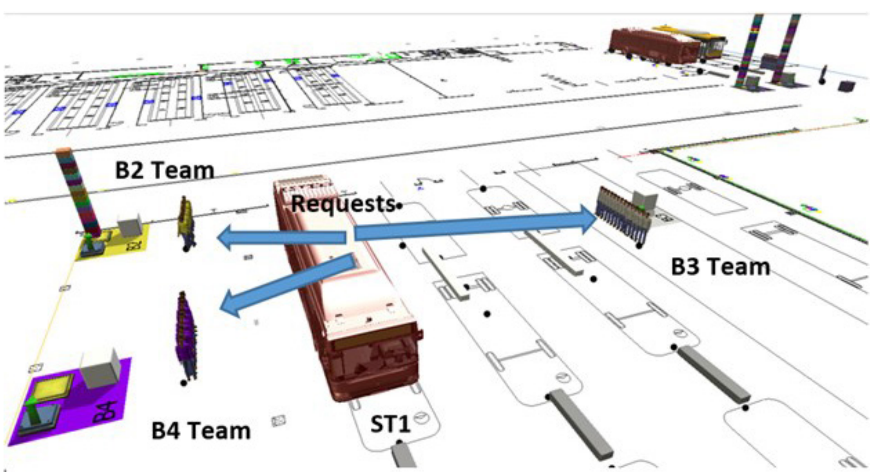

Figure 7: Requests for work from assembling line to Team Agents

Described mechanism is implemented in FlexSim (Fig. 8). The model includes 20 stations – 2 special stations in the beginning of process and 18 stations in three parallel lines (Fig. 1). The work of 23 work teams is modeled – more than 200 contractors. It is possible to change the number of members of work teams and to define new type of bus. The model enables to perform experiments with following reports:

- work team conflicts – situation when the work team finish work after end of the cycle time,
- list of operations which cannot be performed because the time to the end of cycle is shorter than time of operation,
- list of idle time by work team at the end of cycle – to evaluate the team work.

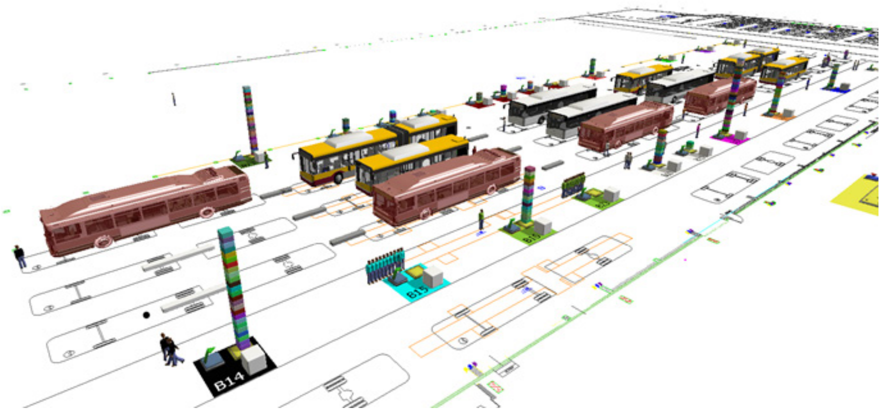

Figure 8: View of bus assembling line in FlexSim

6. Conclusions

The paper presents the research results performed for bus company. The research focus on building the simulation model of work teams work in finish assembling line. To build the model we use mix of DES/ABS approach. As base the DES simulation program FlexSim is used and in this environment we are developing our own agent base simulation tool. To do it we are extending standard FlexSim task executers and task sequence mechanism and built agents mechanism including the rules of communication between them. The model and prepared tools are implemented in bus company to analyze new assembling process. Thanks it company can short the time to make decision about work team work organization. This tool can be used in two levels:

- design level – when new layout and new organization of works are designed,
- operational level – where finding the best solution is needed because of absence of workers or sudden disturbances in assembling process.

Proposed solution enables to short time of modeling, because creation of new team can be performed in very easy way by copy and paste operation and by definition of relation between Team Agent and table of tasks. The user (designer of layout and team workers operations) can focus on solving the problem without deep knowledge of used simulation program.

The paper presents first built model. Model is accepted by bus company so we define the possibilities to extended it by:

- skills matrix of workers – Team agent assign workers to activity based on skills of workers which are saved in this matrix,
- introducing special Contractor Agent – Jumpers – workers which can be shared by many work teams,
- introducing tools which will enable to define optimization task to find the best assigning.

7. Aknowledgement

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