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Work sequence analysis and computer simulations of value flow and workers' relocations: a case study

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Abstract

Several solutions have been proposed for the workload balancing in manual assembly lines with workers' task assignment. Facing the case study of a sheet metal assembly line of transport pallets, the paper addresses the problem of the dynamic task assignment. The walking path minimization is considered in the problem, together with task sequence constraints. A real-time simulation allows to test the solution variations before their implementation.

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Keywords: Workload balancing; computer simulations; assembly; value flow improvement; simulated experiment

1. Introduction

The problem of assembly and manufacturing lines balancing as well as the worker's assignment is widely discussed in literature [2, 6]. Different methods and models are presented and recommended to use in different situations [1, 3]. The main objective in line balancing is to distribute tasks over the workstations and workers in order to minimize the idle time of machines and operators.

The problem of a worker-task assignment is usually solved in two different ways according to literature: with a fixed assignment system or with a work sharing system [10]. In the fixed assignment systems, a worker continues doing the specific task once the assignment has been made, while in the work sharing systems workers are dynamically assigned to workstations or tasks according to the system dynamics. In the fixed assignments, an important issue is to design the assignment policy based on the given knowledge of the workers [9]. In the work sharing, workers have to be flexible, therefore, they have to be cross-trained and they are dynamically shifted from one station (task) to another in order to balance the workload and increase the throughput [4, 5, 7, 8].

Compared with mathematic models, simulation-aided approaches present a more realistic way to solve the task allocation problem. By describing the equipment layouts, the manufacturing logistic process, and the multiple system measurements, the simulation can map real and changing production environment by considering multiple objectives simultaneously [11]. Furthermore, simulation models show flexible and adaptive advantages for an experiment design and what-if analysis.

Our goal is to evaluate the impact of a number of workers and the line management approach (different buffer size) on the workload balancing of workers. In the production line taken as a case study, workload is made by both processing tasks and transportation tasks. Therefore, the objective is to balance the workload comprising process tasks, part transportation tasks and unloaded travel times. Daily travel distance needs to be balanced among operators to increase the quality of work. This a side goal.

The remaining part of the paper is organized as follows. Section 2 describes the industrial problem considered in the paper. Section 3 refers to the possibilities of the manufacturing process simulation and describes the simulation model as well as its implementation in FlexSim. Section 4 presents the

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scenarios used in the simulation, while Section 5 discusses the experimental results obtained in the different scenarios simulated. Finally, Section 6 draws conclusions and states future works.

2. Industrial problem description

The considered industrial process is the manufacturing and assembly of a transport pallet. The pallet is made of sheet, profile and frame. Each part of the pallet is manufactured by a number of stations and then assembled with the other in order to have a final pallet. The tasks are performed manually requiring one to two workers for each task.

The task allocation problem of interest for the company is described as follows. In a manufacturing line, which layout is shown in Fig. 1, workers *w* perform work tasks. A task can be a manufacturing task *mt* or a transport task *tt*. The list of manufacturing tasks is reported in Table 1, while the list of transportation tasks is reported in Table 2. Table 1 includes a description of each manufacturing task, information about the tasks duration and a number of workers needed to perform each task. In table 2 each transportation task is described by giving the starting work station or warehouse, as well as the destination work station or warehouse. Additionally, the transportation content is listed. The time needed to perform each transportation task is presented together with the number of workers needed to perform the transportation task (some parts are heavy and need two people to be carried). Transport tasks *tt* concern transport of materials or products from one work station to another as well as from material storage *MS-1* or *MS-2* to a work station, or from a work station to a ready product storage *PS*.

Manufacturing tasks are performed on work stations *s*. Some manufacturing tasks *mt* can be performed only on one work station *s*. Some other manufacturing tasks *mt* can be performed on different work stations. The list of workstations and the associated manufacturing tasks are presented in Table 3.

The sequence of manufacturing tasks needed to accomplish the whole process is shown in Fig. 2.

In fact, 10 workers work on dedicated work stations based on their experience. The manufacturing tasks as well as the transportation tasks are assigned to workers, and workers are assigned to work stations as presented in Table 4. In some cases one manufacturing task *mt* or transport task *tt* has to be performed by two workers working together.

Currently, the workload is not balanced as some operators work significantly more than others. Fig. 3 presents the workload of workers coming from performing manufacturing and transportation tasks.

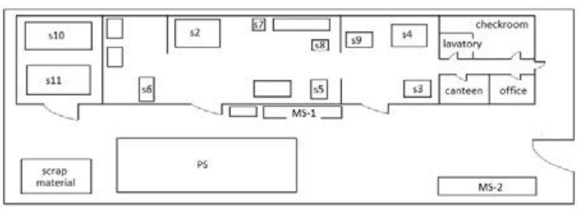

Fig. 1. Layout of a manufacturing line and warehouses.

Table 1. List of manufacturing tasks.

Manufacturing task *mt*	Description of a manufacturing task	Task duration t_{mt} [sec]	Number of workers N_w needed to perform a task
mt1	Sheet cutting	40	2
mt2	Sheet corners cutting	652	2
mt3	Sheet bending	624	2
mt4	Profile cutting	349	1
mt5	Profile incision	504	1
mt6	Holes drilling	1 026	1
mt7	Angles cutting	16	1
mt8	Cup welding	192	1
mt9	Frame welding	304	1
mt10	Sides welding	416	1
mt11	Bottoms welding	120	1
mt12	Building-up	1 187	2
mt13	Assembly	1 212	2

Table 2. List of transportation tasks.

Transportation task number	Previous-next work station *s*	Transported load	Duration time of a task t_{tt} [sec]	Numbers of workers needed to perform a task together N_w
tt1	MS-2-s2	Sheet	20	1
tt2	s2-s3	Cut sheet	20	2
tt3	s2-s5	Cut sheet	15	1
tt4	s3-s4	Sheet without corners	5	2
tt5	s4-s10	Bended sheet	25	2
tt6	s4-s11	Bended sheet	25	1
tt7	MS-1-s6	Profiles	10	1
tt8	s6-s7	Cut profiles	15	1
tt9	s7-s8	Incised profiles	5	1
tt10	s8-s5	Profiles with holes	10	1
tt11	MS-2-s9	Angles	15	1
tt12	s9-s5	Cut angles	10	1
tt13	s5-s10	Frame	20	2
tt14	s5-s11	Frame	20	2
tt15	s5-s10	Cups	15	1
tt16	s5-s11	Cups	15	1
tt17	s10-PS	Transport pallet	15	2
tt18	s11-PS	Transport pallet	15	2