The Issue of Selecting and Schematic Relocation of Mobile Industrial Robots for Flexible Manufacturing System of Technological Park

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February 21, 2025

The issue of selecting and schematic relocation of mobile industrial robots for flexible manufacturing system of technological park

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Annotation

The current state of the problem considered in the material was analyzed, and the purpose, main research questions and application area were determined. Based on the purpose of automating production logistics and transportation for the flexible manufacturing systems (FMS) of the technopark, which is the application area, the structural schemes of the flexible manufacturing modules (FMM) of the technological process, the types of mobile industrial robots (MIR) moving in these modules and their movement trajectories were considered. In order to correctly select the types of mobile industrial robots for every FMM of FMS, the structural schemes of the modules, working zones, and movement trajectories were established. In order to select the type of mobile industrial robot for the FMS, an algorithm was developed using the fuzzy logic principle of the logical modeling method. An algorithm was developed based on the linguistic term description method to ensure the efficient selection of the type and type of mobile industrial robot corresponding to the purpose of the FMS.

Keywords: flexible manufacturing system, mobile industrial robot, manufacturing module, fuzzy logic, linguistic term.

I. Introduction

At present the transfer of new information and automation technologies to industrial sectors and technoparks is considered one of the important issues in order to ensure high economic development of countries. One of the enterprises widely used in technological parks is flexible manufacturing systems (FMS) [1, 2]. Increasing the efficiency of designing the FMS of a technopark and its standard and non-standard elements, which has a complex structure, numerous mechanical and electronic, automated information, control systems, logistics, transport vehicles, industrial robots, manipulators, etc. active elements, is considered one of the important scientific issues. In this sense, it is necessary to properly organize the stages of designing the non-standard element of the FMS of the technopark - a mobile industrial robot - and their automation It is required to solve the issues of information provision, development of mathematically determined algorithms and models.

[3, 4] analysis shows that in order to achieve high productivity of the machine-building MIS of the technopark and automation of the technological process to a high degree, its production modules and areas should be equipped with robotics, automated supply, and logistics transport complexes, and its warehouses should be equipped with mobile industrial robots, and machine-building technology should be organized on the basis of standard structural schemes of digitally controlled machines, technological equipment, and vehicles (Fig. 1).

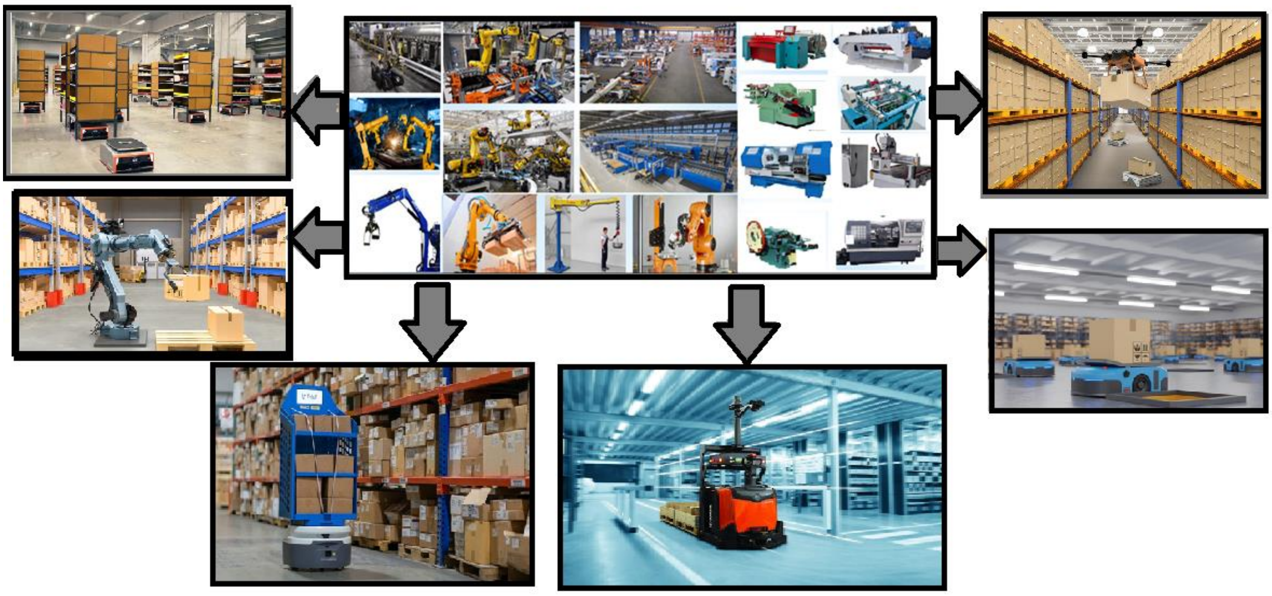

Fig. 1. Application of robotics, digital machine tools, transport, technological equipment and mobile industrial robots servicing warehouses in the machine-building Tenopark's MIS

II. The application object description and schematic analysis

Mobile industrial robots of various types are used to ensure the efficiency and automation of the activities of robotics, digital machines, transport, technological equipment, and warehouses of the technopark's FMS [5, 6].

Mobile industrial robots used in the MIS perform the following technological operations:

1. Delivery of designs to the mechanical engineering and mechanical processing import areas of FMS;
2. Delivery and assembly of finished products to the warehouse of FMS;
3. Collection and transportation of waste products from the production lines of the technopark's mechanical engineering waste management system.

In order to correctly select the types of mobile industrial robots for the machine-building flexible manufacturing system, let's analyze the application object. MIS, which consists of technological operations such as cutting, heating, polishing, drawing, drying, cold welding, straightening, cutting, heating, slotting, channeling, drying and assembly on aluminum material, is used to produce evaporators. At each of the mentioned production stages, robotic complexes, automatic vehicles, and positioning manipulators are used. However, in the production areas of the MIS, technical supply, logistics and transportation operations are required. In this regard, let's divide the application object into production stages and determine the types of mobile industrial robots that perform the functions of service, supply, delivery, loading, transportation and assembly for them (Fig. 2).

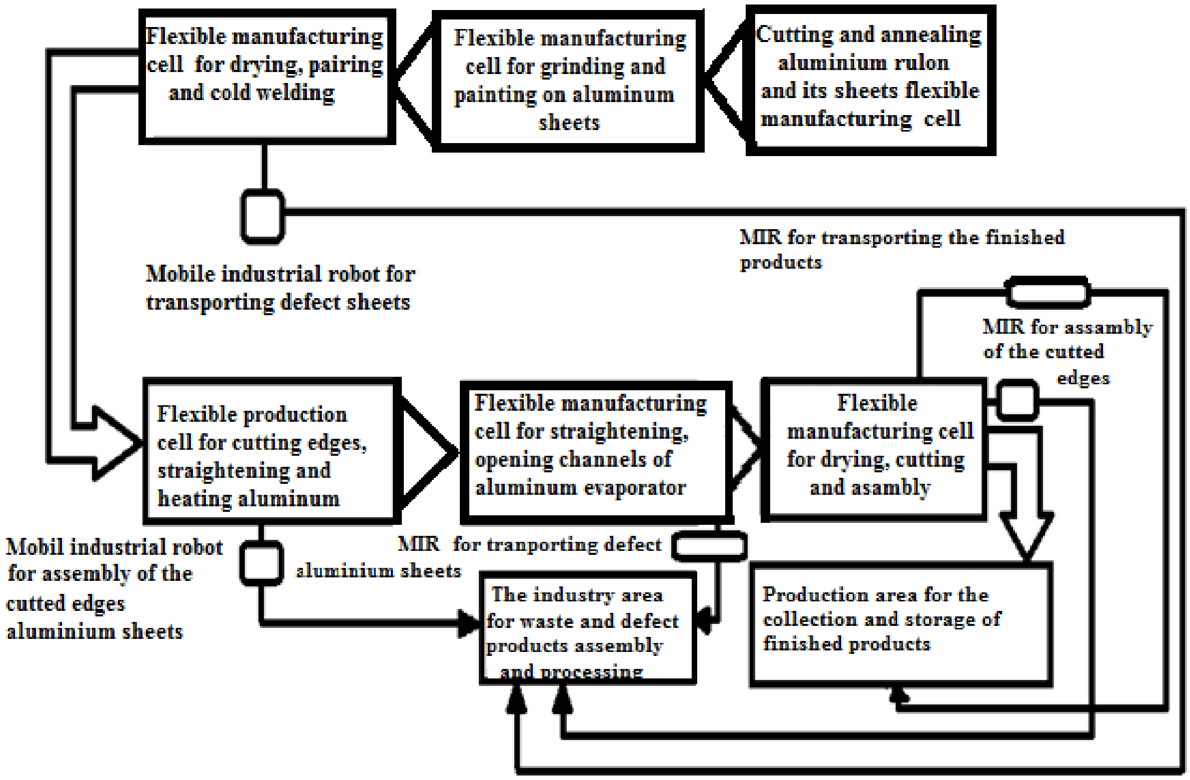

Fig. 2. Mobile industrial robots used in the applied FMS
and their route map

As can be seen from Figure 2, the aluminum evaporator flexible manufacturing system (FMS), which is the application object, consists of 6 production areas. The technological operations performed sequentially in the production areas of the FMS are described in the following set:

$$X_i \in \{X_1, X_2, \ldots, X_6\},$$

where X_1 - cutting the aluminum coil into sheets and heating them; X_2 - polishing and drawing the aluminum sheets; X_3 - drying the aluminum sheets and cold welding them by pairing them; X_4 - cutting off the excess parts of the aluminum sheet, straightening and heating them; X_5 - straightening the aluminum sheet, opening the slots and channels; X_6 - drying, cutting and assembling the channels of the aluminum sheet.

Analysis of X_i technological operations shows that during the product preparation process, aluminum waste is generated as a result of cutting the aluminum sheet, which causes pollution of the production area. On the other hand, in the process of preparing the product in a separate production area (in particular, in the drawing, slotting and grooving devices and equipment), defective products are produced, which must be removed. At the end of the technological process, the operations of collecting, completing and storing finished products in warehouses must be performed.

One of the important issues is the use of freight vehicles to remove waste and defective products to a special processing area and to ensure that finished products are collected, assembled and placed in the correct positions in the warehouse. Considering that the analyzed application object consists of complex technological operations, requiring heavy physical lifting and transportation operations, it is more appropriate to use efficient and innovative automated technology for this type of work.

Analysis of modern innovative automated technologies used in the production facilities of the technopark [7] shows that a wider range of mobile industrial robots are being applied. The mobile industrial robots analyzed in the introduction of the material belong to the group of standard logistic load-carrying systems. However, taking into account the technological characteristics of the application object, it would be appropriate to use both standard and new-design non-standard mobile industrial robots for the MIS.

So, let's look at the selection and design of standard and non-standard mobile industrial robots (MIR) for the 6 production areas of the flexible manufacturing system for aluminum evaporators, the object of application.

III. Design object requirement definition and selection algorithm creation

The requirements for the design of standard and non-standard mechatronic devices of the FMS are determined starting from the initial stage [8]:

1. Being innovative;
2. Simplicity of structural design and originality;
3. Stability and reliability of the technological process;
4. Equipping modern production technologies with automated control and network systems;
5. Application of artificial intelligence technology.

The complex design process of non-standard MIR for the Tenopark's machine-building MIS is carried out in stages [9]. Starting from the initial design stage, the application of artificial intelligence technology is required to increase efficiency:

1. Proper expert analysis and selection of types of non-standard MIR mechatronic devices;
2. Proper selection and design of the mechatronic device assembly structure of non-standard MIR;
3. Correct, accurate planning and modeling of technological processes of non-standard MIR mechatronic elements in the applied MIR;
4. Automation and management of operations of mechatronic parts of production MIR based on new computer and network technology;
5. Monitoring the assembly, correct assembly and quality of the product based on MIR's technical control technology for mechatronic elements.
6. Automation of the complex execution of the above-mentioned design procedures 1 – 5 based on a single intelligent interface (Fig. 3).

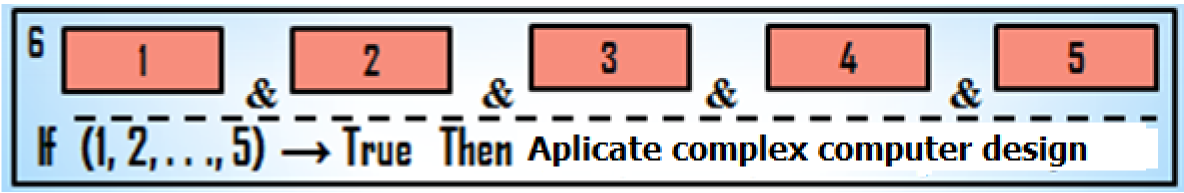

Fig. 3. Scheme of automation of complex execution of the above-mentioned design procedures 1 – 5 based on a single intelligent interface

At the 1st stage, a survey is conducted based on the project *task to design a non-standard MSR for the application object. Based on the survey,* an analysis of existing mobile industrial robots used in enterprises producing aluminum evaporators is carried out and a database management system (DBMS) of their prototypes (Pi) is formed [9]. Similarity conditions are determined for the correct selection of an analogous project from the DBMS of the selected prototype projects:

$$Y_i = \begin{cases} [0\ 1],\ \ if\ MIRi\ prototype\ applied\ suitable: \\ low\ (\mu_{ptua} = 0{,}3),\ average\ (\mu_{ptuo} = 0{,}5),\ high(\mu_{ptuy} = 0{,}7); \\ [0\ 1],\ \ if\ MIRi\ prototype\ construction\ innovate: \\ low\ (\mu_{ka} = 0{,}3),\ average\ (\mu_{ko} = 0{,}5),\ high(\mu_{ky} = 0{,}7); \\ [0\ 1],\ \ if\ MIRi\ prototype\ technology\ innovate: \\ low\ (\mu_{ta} = 0{,}3),\ average\ (\mu_{to} = 0{,}5),\ high(\mu_{ty} = 0{,}7); \\ [0\ 1],\ \ if\ MIRi\ prototype\ automation\ level: \\ low\ (\mu_{ada} = 0{,}3),\ average\ (\mu_{ado} = 0{,}5),\ high(\mu_{ady} = 0{,}7) \end{cases} \quad (1)$$

where $\mu_{ki},\ \mu_{ti},\ \mu_{adi}$– are the coefficients of affiliation of the prototype's suitability for its purpose, the selection conditions according to its design, technological innovation, and degree of automation, respectively.

According to (1), based on the design, technological innovations and degrees of automation of projects from the MIRi DBMS, the prototype project of MIRi, which is closer to these indicators and also more economically efficient, is selected as an analogue.

Thus, from formula (1) and the technical characteristics of the analyzed prototypes, as well as the logical conclusions of the prototype projects of the MIRi stored in the database of innovative projects of the DBMS (DBi), are deduced. If the logical deduction algorithm is carried out according to the design novelty of the MSRi, then the expression should be written as follows:

$$\begin{aligned} &\text{If } Yi \in [0\ 1],\ where\ Y_1 / (\mu_{ptuo} = 0{,}5); \\ &where\ Y_2 / \ low\ (\mu_{ka} = 0{,}3); \\ &where\ Y_3 / \ average\ (\mu_{to} = 0{,}5); \\ &where\ Y_4 / low\ (\mu_{ada} = 0{,}3). \end{aligned} \quad (2)$$

Based on (2), an experimental test is conducted to evaluate the innovative design of the MIRi prototype and a graph is constructed (Fig. 4). Analysis of this graph shows that the evaluation of the MIRi project indicators (Table 1) is carried out according to the associativity principle, which allows proposing and implementing new project tasks until the solution Y_i *is fully achieved.*

Table 1. Fuzzy linguistic evaluation indicators of the MIRi project indicators

Y 1/M 1	*average*	0. 5	1
Y 2/M 2	*low*	0.3	1
Y 3/M 3	*average*	0. 5	1
Y 4/M 4	*low*	0.3	1

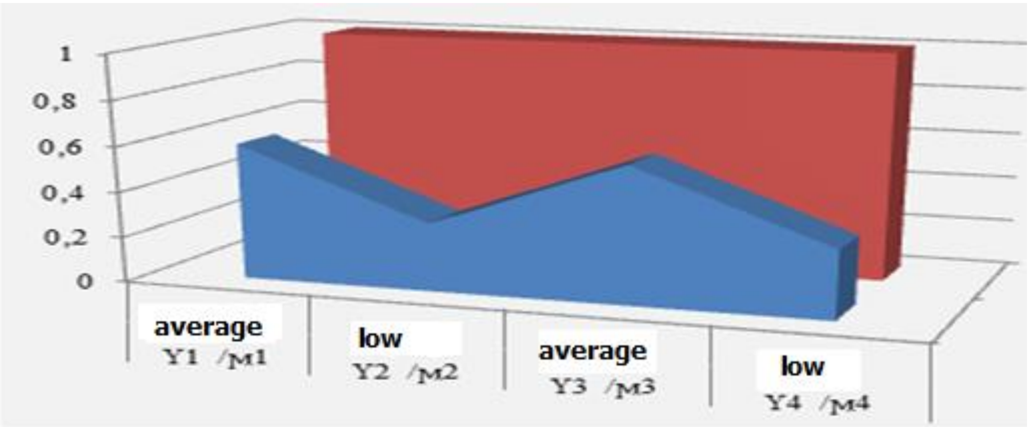

Fig. 4. For assessing the innovativeness of the MSRi prototype project experimental graph

As can be seen from Figure 4, to fully address the issue of selecting and designing an MIR, it is necessary to increase the compliance levels for each parameter according to the following values:
1. The correspondence of the prototype of MIRi to the designation is 0.3, i.e. $M1 \rightarrow high\ (\mu_{ptuy} = 0{,}9)$required to be increased to. If it is not possible to deliver according to the intended purpose, ***according to its purpose area performing close technological operations must be searched for***.
2. In terms of the constructive novelty of MIRi, it is as 0.5, i.e. $M\ 2 \rightarrow$ If the design of the MIRi is old, $high\ (\mu_{ky} = 0{,}9)$***a new design project of the MIRi must be developed*** to ensure the novelty of this parameter.
3. In terms of technological innovation of MIRi, it is as 0.3, i.e. $M3 \rightarrow high\ (\mu_{ty} = 0{,}9)$. If there is a flawless technology, the MIRi that ensures the innovation of this parameter ***should work with the new technology***.
4. In terms of the automation level of MIRi, it is 0.5, i.e. $M\ 4 \rightarrow$ If the project has an old level of automation, $yüksək\ (\mu_{ady} = 0{,}9)$***a new automation scheme for MIRi should be developed*** to ensure the reliability, speed and accuracy of the implementation of this parameter .

Thus, based on (1) and (2), the following decisions are made in order to develop a new MIR project suitable for the application object of the analog MIR selected based on the analysis of MIRi and prototype projects (aluminum evaporator flexible manufacturing system):
1. A search should have been conducted for a site that performs technological operations close to its intended purpose.
2. A new design project for MIRi should be developed.
3. MIRi must work with new technology.
4. A new automation scheme for MIRi should be developed.

In the mechanical engineering MIR of the technopark, a fuzzy software tool is used in the search, analysis, decision-making and selection procedures of MIRi. Linguistic terms are defined (%) for the selection of MIRi prototypes (Pi): very low [0 10 20 30]; low [20 30 40]; average [30 40 50]; high [40 50 60]; very high [50 60 70 80]. The corresponding μ_i membership coefficient for each linguistic term is defined [10]:

$$\mu_i \in \{0.1, 0.3, 0.5, 0.7, 0.9\} \quad (3)$$

the accepted linguistic terms, **their designations**, and the corresponding membership coefficients [10]:

$$X = {}^{\mu_1}/_{very\ low} + {}^{\mu_2}/_{low} + {}^{\mu_3}/_{average} + {}^{\mu_4}/_{high} + {}^{\mu_5}/_{very\ low} = {}^{0.1}/_{(0\ 10\ 20\ 30)} + {}^{0.3}/_{(20\ 30\ 40)} + {}^{0.5}/_{(30\ 40\ 50)} + {}^{0.7}/_{(40\ 50\ 60)} + {}^{0.9}/_{(50\ 60\ 70\ 80)} \quad (4)$$

A graphical representation of expression (4) is constructed. Here, the dependence of ***very low*** and ***very high*** linguistic terms on the membership coefficients is depicted in a trapezoidal shape, and the dependence of other linguistic terms on the membership coefficients is depicted in a triangular shape, as shown in Figure 5.

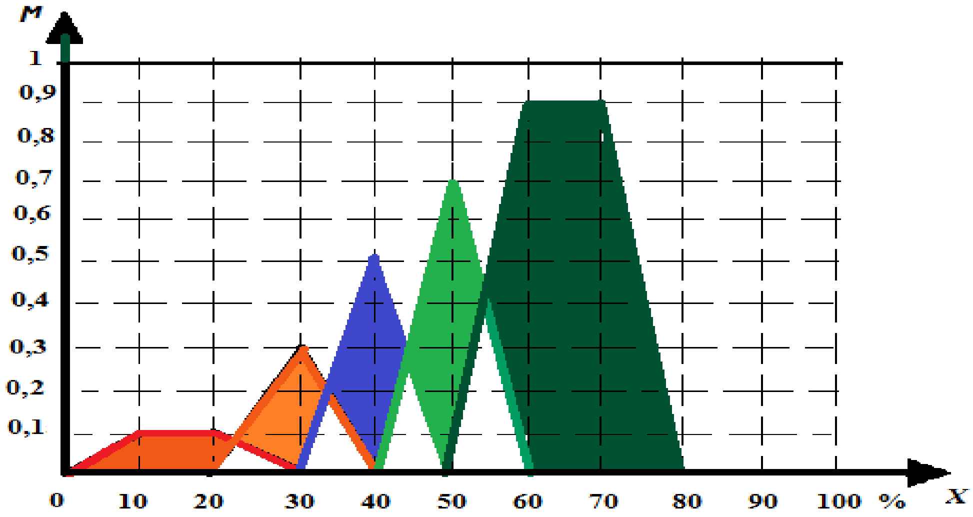

Fig. 5. Graph of the selection function based on the properties of MIRi

From expression (4), the selection conditions of MIRi are determined according to the linguistic terms of prototype suitability, designer, technological innovation, and degree of automation. A logical expression is constructed step by step for the selection of MSRi according to the linguistic terms of each parameter:

Conclusion

Algorithm for selecting the prototype of the MIRi according to its purpose

If If the suitability of the MIRi prototype **for its intended purpose is very low** (0 10 20 30),

Then, the selection of the prototype of that MIRi **according to its purpose** should be accepted as 10 ÷ 20%;

If If the suitability of the prototype of the MIRi **for its intended purpose is low** (20 30 40),

Then, 30% should be accepted **for the purpose of** selecting the prototype of that MIRi ;

If If the suitability of the MIRi prototype **for its intended purpose is average** (30 40 50),

Then, the selection of the prototype of that MIRi **according to its purpose** should be accepted as 40%;

If If the suitability of the MIRi prototype **for its intended purpose is high** (40 50 60),

Then, the selection of the prototype of that MIRi **according to its purpose** should be accepted as 50%;

If The MIRi prototype is **very** suitable **for its intended purpose. if it is high** (50 60 70 80),

Then, the selection of the prototype of that MIRi **according to its purpose** should be accepted as 60 ÷ 70%;

According to its purpose, the logical output of the algorithm established above if the selection is accepted as 60 ÷ 70%, then the selection according to other characteristics of the MIRi is continued by an analogous principle. Thus, the design of the prototype of the selected MIRi, its technological characteristics and the degree of automation of the mechatronic parts are evaluated.

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