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THE USE OF DATABASE IN THE PLANNING OF ASSEMBLY WORKPLACES AND SYSTEMS

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Abstract

In the context of advancing technologies and industrial modernization, attention must be directed not only towards production technology but also assembly processes. This article aims to formulate a conceptual solution for rationalizing assembly workplaces, creating an integrated methodology and tools. The theoretical segment reviews the current state of assembly workplaces and systems. An analysis based on predefined criteria reveals the need for a classification system. The practical section proposes a methodology leveraging databases, algorithms, and simulation. A crucial aspect is an electronic database, a key component for rationalizing assembly workplaces and systems in both new and existing production systems.

Keywords:

Assembly, Rationalisation of Assembly Workplaces and Systems, Database, Assembly Planning

1 INTRODUCTION

Studies of new industrial production projects show that the current era requires the application of new approaches at all stages of preparation and implementation. It can be said that the products produced by the engineering industry are highly sophisticated at all levels [Kiran 2019].

Assembly, as the process leading to the completion of products, is a costly part of the production system and is usually the most time-consuming part of the production unit. If the assembly process is not designed correctly, the assembly system or workplace will tend to produce a higher percentage of defective product pieces. This condition results in financial costs over budget and also time variances that must be addressed promptly, even while the assembly process is in full operation.

As industrial manufacturing is still one of the leading fields, innovative solutions are often proposed in modern industrial practice to improve the flow of entire production or assembly processes [Schindlerova 2023].

Modern design and planning of production and assembly systems or the solution of complex parametric models requires the integration of familiar and commonly used design and planning methods with computer technology. It is important that the computer technology used is equipped with the necessary tools, such as software for the design and simulation of manufacturing and assembly processes or other tools [Krajcovic 2022].

There is a trend nowadays that companies are increasingly implementing new technologies in production, but they need to be able to combine them. It is important for companies to be aware of current developments and to understand the added value of new and innovative solutions [Wiendahl 2015, Kristak 2018].

Innovative approaches to production design and assembly aim to provide users with better quality designs in less time [Sammen 2020].

The status and importance of the pre-production stage are constantly increasing in line with scientific and technological developments. This stage involves activities with a conceptual and creative character. The correct design and planning of production and assembly processes, their functionality and performance prediction can influence the entire operation of a factory.

The expansion of pre-production stages is also due to the shortening of product life cycles and the increase in product variability. As a result, there are constant changes and rising costs in production processes that can be influenced even before production starts. It is insufficient to simply look for rationalisation potential in production, as it is no longer enough to reduce costs and tighten up production processes as such. Waste can also be identified in the previously mentioned pre-production stages, where waste is the result of incorrect design of the system used or incorrect planning of the production and assembly processes.

The design of production and assembly processes, specifically assembly systems, is a complex process that involves not only assembly technology but also material flow, information flow, personnel, design and selection of premises, etc. Dynamic design and planning approaches, integration of the environment, and the design of systematic organisation, supported by computer technology, are becoming increasingly important [Ciganekova 2017, Kucerak 2017].

The Digital Factory concept can simply be understood as a concept in which the entire factory exists in digital form. The factory is created before its physical realisation and during its existence through the design, management, operation, floating, analysis and simulation of all the processes that take place in it. The use and application of computer technology is the basis for the realisation of such a concept. In addition to the fundamental CAx technologies, we can also include PLM systems (which include production simulation) and databases [Vaclav 2011, Trebuna 2019].

A PLM system, as a software solution, should create a dynamic infrastructure of computer applications for the enterprise to handle all product data throughout its lifecycle. PLM systems include software modules such as design, planning, manufacturing, people, simulation, etc. [Trebuna 2019]. Using accurate digital modelling, simulation and 3D visualisation, design and planning professionals can visualise and analyse future manufacturing and assembly processes [Matusova 2015]. Such evaluation allows key design decisions to be made promptly while limiting errors that could occur during the ramp-up phase of production. In addition to the development of future manufacturing and assembly processes, modelling and simulation can also be used to rationalise and optimise existing production [Vaclav 2023].

Simulation is a versatile method that allows you to create different scenarios and observe what the effects would be in real life. This enables rapid testing of multiple parameters and optimisation of production processes [Uriarte 2018]. Through simulation, production variables, space and manufacturing processes can be optimised, and entire manufacturing processes can be simulated before they are put into practice as a decision-support tool [Barrera-Diaz 2018, Kwok 2019, Shao 2019]. Simulation models are a standard part of decision support in production planning and management [Gregor 2018].

Databases can be used as an additional tool in production design and planning. Today we can find different definitions of this topic. This is attributed to the subjective viewpoint of each author. However, we can simply define it as a shared data structure that contains the end-user data, i.e. everything that is of interest to the user, and the metadata, i.e. the data about the data, through which is integrated and managed. Databases are characterised by properties such as [Delikat 2006, Berrington 2017]:

- A complex file - it can consist of many different files,
- data is systematically stored, organized, and sorted in a structured format,
- the data are connected in logical relationships.

In line with the trend towards digitalisation of the product creation process, as well as the design and planning process of production and assembly groups, the creation of digital models and their verification in a virtual environment is becoming increasingly important. Given the fact that the creation of such models is often a routine and time-consuming task, the creation of databases plays an important role in this respect.

2 CONCEPTUAL DESIGN OF THE METHODOLOGY FOR RATIONALISATION OF ASSEMBLY WORKPLACES AND SYSTEMS

The methodology essentially means an explanation or delineation of the procedure for a particular activity. From the perspective of technical practice, methodology can be defined as a detailed description of activities organized in a time schedule to achieve the highest possible efficiency of the process.

The subject of this paper is the conceptual design of a methodology for the rationalisation of assembly workplaces and systems. Advances in the field of combining science and technology have been taken into account in the design of the methodology. Since computer support and its tools in the field of design, planning and planning have evolved and modernized considerably in the last period, we decided to use this potential in solving the current problem. Therefore, the conceptual design of the methodology uses modern tools such as databases, algorithms and computer simulation of production and assembly systems. The methodology is useful in the initial phase of introducing a new production or assembly or upgrading an existing production because it combines areas such as design and planning in terms of a systems approach. The aim is, through the use of the proposed methodology, to build the initial structure of the assembly system with respect to the specified input attributes and parameters and thus reduce the time required for the design and planning phase. The design of a satisfactory assembly system is a complex problem, and there are many variables and options that can be identified as the correct solution.

By utilizing an appropriate methodology, it would be possible to shorten the design time of the assembly system and workplace while simplifying decision-making processes when selecting the right solution and eliminating unsuitable options. In practice, this would mean a smoother initiation of planning and implementation for subsequent stages of introducing production or making changes to existing production setups. In our case, we have defined this conceptual methodology proposal as an algorithm.

In order for the algorithm to fulfil its purpose and work efficiently, it needs to have a lot of information or data about the assembly systems and workplaces. This information and data are contained in an electronic database, which is an essential part of the algorithm. This database will be explained in more detail in the following sections of the paper. The conceptual design of the methodology is shown in the form of a flow chart in Fig. 1.

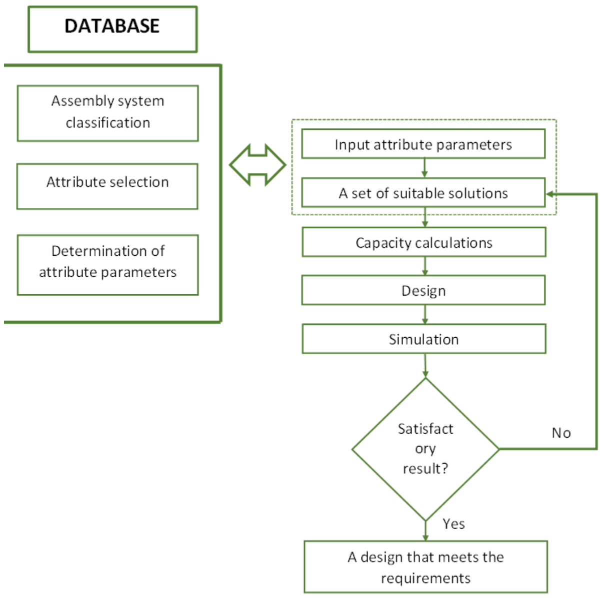


Fig. 1: Algorithm of the methodology

The basic scheme of the algorithm has defined individual steps that represent the sequence of steps of the proposed methodology. The algorithmic solution of the methodology works on the following principle. The user selects parameters in the electronic database, based on the set priority attributes, which are the focus for the planned production. Subsequently, the electronic database generates an assembly system meeting the specified parameters or a set of suitable assembly system structures. The selection of the most suitable assembly system is followed by the calculation of capacity calculations. As the next step, the selected design is verified by simulation. If the simulation model does not confirm the assumptions of a suitable assembly system for the planned production, it is necessary to return to the step of evaluating the set of suitable solutions and select another assembly system that meets the input parameters. The other steps in the process are then repeated.

If the simulation model proves to be suitable and confirms the assumptions of the assembly system design, we can speak of a compliant design. Such a model is also suitable for future planning of modifications to the assembly system or workplace in terms of timesaving and can also serve as a test model when planning changes in production.

3 DATABASE CREATION AND ITS IMPORTANCE

The electronic database is one of the most important and necessary components, not only for the construction of the conceptual design of the methodology, but also for the proper functioning of the algorithm.
Before creating the electronic version of the database, it was important to define and think about the principle on which the database will work and what information it will contain. The basic scheme of the database is shown in Fig. 2. The database contains the following elements:

- Database - Categories - in this case represent the classification of assembly system structures.
- Category - Attributes - each category has attributes assigned to it, which in our understanding represent the properties of a particular assembly system structure.
- Parameter - each Attribute has a parameter assigned to it.

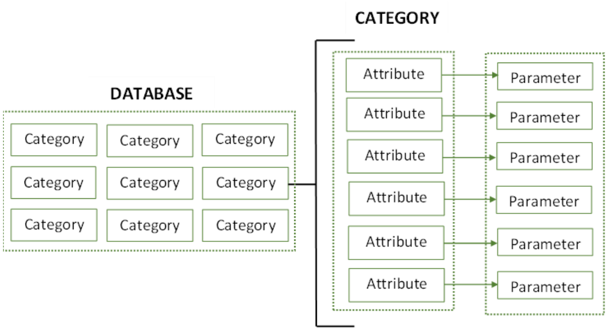


Fig. 2: Database scheme

The creation of a database of assembly system structures is described schematically in Fig. 3.

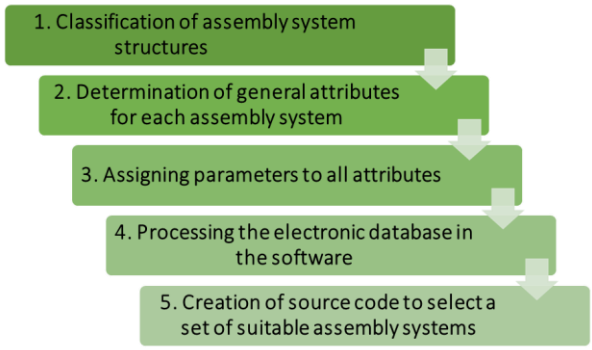


Fig. 3: Database creation scheme

Step 1 - Classification of assembly system structures - The assembly systems used within the database were classified based on their organisational and technological layout. From the collected knowledge, four basic principles of arrangements were identified, which are further subdivided into subgroups according to conceptual variants. With regard to the division of assembly systems, necessary for the creation of the database, we drew from the research work of Ing. Martin Benovic, PhD. Since the author has studied the field in detail in his scientific work and has established a detailed classification of assembly systems, this classification seemed to be the most appropriate with regard to the creation of an electronic database. The basic structures of assembly systems classified according to the organizational-technological arrangement are as follows [Benovic 2013]:

- Integrated assembly systems IAS,
- assembly lines AL,
- stationary assembly systems SAS,
- external assembly of extremely large products EA-ELP.

Fig. 4 shows part of the variants of possible structures of assembly systems contained in the database.

Integrated Assembly Systems - IAS

Stationary Integrated Assembly Systems (S - IAS)

S - IAS - a Basic stationary integrated assembly system
S - IAS - b Stationary integrated assembly system with step tools
S - IAS - c Stationary integrated assembly system with step part tray
S - IAS - d Stationary integrated assembly system with step part tray and tools

Batch Integrated Assembly Systems (B - IAS)

B - IAS - a Stationary pallet for manual assembly
B - IAS - b Stepping circular pallet
B - IAS - c Chain stepping pallet
B - IAS - d Positioning pallet
B - IAS - e Mechanised integrated assembly station

Circulating Integrated Assembly Systems (C - IAS)

C - IAS - a Circulating worker with tools system
C - IAS - b Circulating worker with product system

Robotic Integrated Assembly Systems (R - IAS)

R - IAS - a Robot cooperation system
R - IAS - b Robotic transport assembly system

Fig. 4: An example of the classification of assembly systems in the database

Step 2 - Determination of General Attributes - The decision table has included the attributes that most accurately describe and characterise the use of the evaluated assembly system structure. The selection of attributes and their parameters are generally known to experts in the field. It was based on theoretical knowledge, practical experience and the requirements placed on the assembly systems or the quality of the assembly. As can be seen in Fig. 5, the general attributes that apply to each assembly system in the database include, for example, annual production volume, product size, number of components, economic difficulty, level of automation, and so on.

Assembly system selection form — Reset

Attribute	Parameter
Annual production volume [pcs/year]	
Product size	
Product complexity	
Number of components	
Component orientability	
Level of humanisation of work	
Level of flexibility	
Staff qualifications	
Economic difficulty	
Energy consumption	
Initial investments	
Space requirements	
Equipment utilisation rate	
Level of automation	

Suitable systems: — Search for suitable systems

Fig. 5: Assembly system selection form

Step 3 - Assigning parameters to attributes - In this step, parameters were assigned to each attribute in the evaluation table. In this case, the evaluation was also based on scientific literature and on practical experience. The parameter represents a specific number, but can also represent an interval and in some cases a verbal rating such as High - Medium - Low, which is determined based on empirical experience and subjective evaluation (Fig. 6).

C - IAS
C - IAS - a
Circulating worker with tools system

Close review

ATTRIBUTE	PARAMETER
Annual production volume [pcs/year]	1000 - 10000
Product size	Heavy products
Product complexity	Simple - Complex
Number of components	10 - 100
Component orientability	All products
Level of humanisation of work	High
Level of flexibility	In real time - With a variation lasting a maximum of one shift
Staff qualifications	Medium - High
Economic difficulty	Medium - High
Energy consumption	Medium
Initial investments	Medium - High
Space requirements	Medium - High
Equipment utilisation rate	Medium
Level of automation	Manual - Partially mechanised and Automatised assembly

Fig. 6: Evaluation table

Step 4 - Processing the electronic database in the software - The basic version of the electronic database is processed in Microsoft Excel. This program was chosen based from the following reasons:

- In case of switching to a more complex database system, Microsoft Excel can be used as a source file for importing spreadsheet entries into other database systems (e.g. Oracle),
- Microsoft Excel is able to work with the simulation software,
- uses a less user-intensive programming language, namely Visual Basic for Applications (VBA), which is not as demanding in terms of programming compared to other more complex programming languages,
- is affordable for everyone.

Step 5 - Creation of source code to select a set of suitable assembly systems based on input parameters - The source code was created using the VBA programming language. It is set up to evaluate the attribute parameters of all the assembly system structures present in the database according to the input parameters and select only one particular assembly system or a set of those assembly systems that satisfy all the input parameters entered by the user. The user can choose any parameter from the pre-defined attributes, but from literature studies and practical experience, product size and annual production volume are presented as important. It is therefore recommended to give priority to specific attributes. If the intersection of these attributes parameters results in a set of more suitable assembly systems, the user can proceed by selecting further attribute parameter until he reaches the set that is optimal for him. However, a situation may arise where the user selects input attribute parameters such that the database does not find an intersection of suitable options. In this case, a dialogue box will alert the user to this fact.

3.1 Example of Using an Electronic Database

The following example illustrates the use of an electronic database of assembly system structures where some of the necessary requirements for new production have been specified by the customer. The customer has specified the following production requirements:

- annual production volume in number of pieces per year - 9000 pcs,
- product size - small products,
- initial investment for new production – low,
- staff qualification - medium.

The entered requirements were entered in the electronic database into the Assembly System Selection Form (Fig. 7).

Assembly system selection form — Reset

Attribute	Parameter
Annual production volume [pcs/year]	9000
Product size	Small products
Product complexity	
Number of components	
Component orientability	
Level of humanisation of work	
Level of flexibility	
Staff qualifications	Medium
Economic difficulty	
Energy consumption	
Initial investments	Low
Space requirements	
Equipment utilisation rate	
Level of automation	

Suitable systems: — Search for suitable systems

Fig. 7: Step 1 – Entered requirements

After entering the parameters of the selected attributes in the form, the selection is confirmed with the "Search for suitable systems" icon and the electronic database scans and searches for a specific assembly system or a set of assembly systems that meet the specified parameters. The matching assembly systems will be displayed at the bottom of the "Suitable systems" section. As can be seen in Fig. 8, in this case the database has only evaluated one assembly system as suitable, namely the "Basic Stationary Integrated Assembly System".

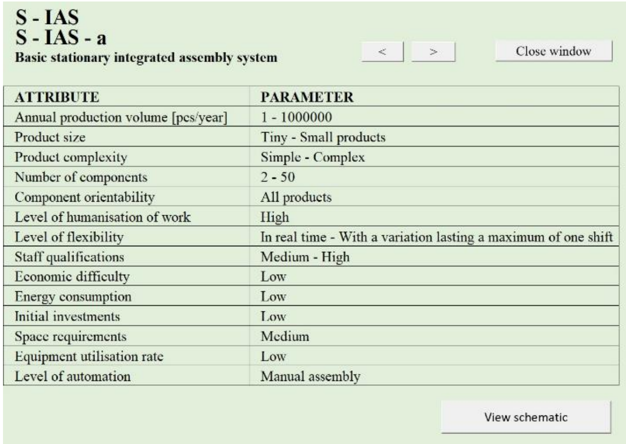
Attribute	Parameter
Energy consumption	
Initial investments	Low
Space requirements	
Equipment utilisation rate	
Level of automation	

Suitable systems: — Search for suitable systems

S - IAS - a

Fig. 8: Step 2- Choosing a suitable assembly system

The user then clicks on the selected system (marked in blue) to open the corresponding assembly system tab, where, in addition to the attribute parameters he entered, he can also see the remaining attributes with parameters specific to the current assembly system (Fig. 9).



S - IAS
S - IAS - a
Basic stationary integrated assembly system

ATTRIBUTE	PARAMETER
Annual production volume [pcs/year]	1 - 1000000
Product size	Tiny - Small products
Product complexity	Simple - Complex
Number of components	2 - 50
Component orientability	All products
Level of humanisation of work	High
Level of flexibility	In real time - With a variation lasting a maximum of one shift
Staff qualifications	Medium - High
Economic difficulty	Low
Energy consumption	Low
Initial investments	Low
Space requirements	Medium
Equipment utilisation rate	Low
Level of automation	Manual assembly

Fig. 9: Step 3 - The selected assembly system and its attributes and parameters

In addition to the assembly system attributes and their associated parameters, the assembly system tab also contains an icon called 'View Schematic'. Clicking on this icon will show the user the basic schematic of this assembly system, including the legend. This diagram is used to give the user a better idea of the assembly system (Fig. 10).

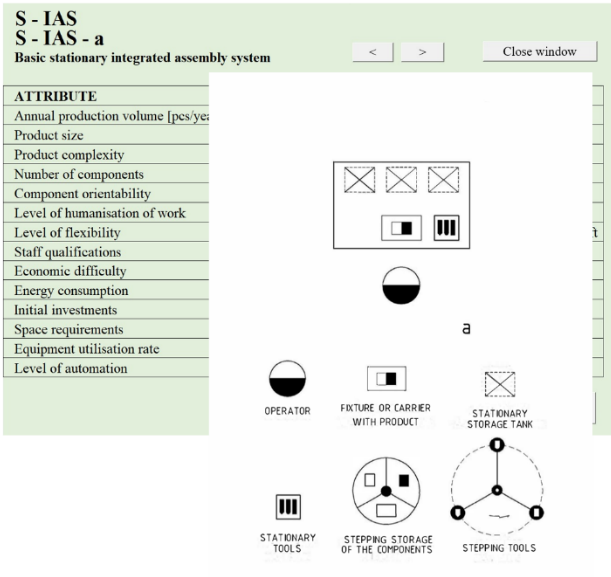


Fig. 10: Basic schematic of assembly system

According to the conceptual design of the methodology, the next step is the determination of the capacity calculations and then the simulation of the selected design, which have been described and schematically illustrated in the previous section, namely Fig. 1. With respect to the capacity calculations, this step could be simplified by designing and creating an interactive capacity calculator that could work based on the data selected by the algorithm. In addition to the capacity calculations, the next step will be to create the simulations needed to verify the correctness of the proposed methodology. However, these steps are the subject of further research and are therefore not described in detail in the current publication.

4 CONCLUSIONS

With the development of smart technologies, the familiar concept of the digital enterprise can be extended to the design and planning of assembly workplaces and systems. Thanks to innovative technologies, companies can easily and efficiently design and validate new production and assembly solutions before real production begins.

The main objective of this paper was to present the conceptual design of a methodology for the rationalisation of assembly workplaces and systems. The methodology is especially valuable during the initial stages of introducing new production or assembly or improving existing production, as it is structured in such a way as to combine areas such as design and planning in terms of a systems approach. The aim was to use the proposed methodology to build the initial structure of the assembly system concerning the specified input criteria and parameters, thereby reducing the time required for the design and planning phase. The methodology was presented and illustrated in the form of an algorithmic solution. The first important step of the methodology - the design and creation of an electronic database - was also presented and described as part of the paper. The design and creation of the database was defined and described in the paper as a series of steps.

The creation of a database, combined with a suitable algorithmic solution, can provide a useful tool for use in the pre-production stages. The use of such an approach to create a design and then a simulation model could not only reduce design and planning times but also provide a simulation model that could be used for further planning and verification of changes.

As stated earlier, additional research will focus on the subsequent stages of the algorithmic solution, specifically the development of an interactive capacity calculator and the creation of simulation models for the final verification of the functionality of the methodology as a whole. If positive outcomes are achieved, it would be possible to incorporate the methodology into a software solution, which would allow us to talk about computer-aided design and planning in the field of assembly workplaces and systems.

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