White Paper on Results of Working Group “Open Digital Factory”

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1. Objective of the working group, “Open Digital Factory”

The execution of simulation projects in the field of production planning and logistic system planning is no longer a novel feature; in fact, this approach now constitutes an integral part of the overall planning process, especially in the automotive and associated supply industries. Nevertheless, simulation projects of this kind tend to be of a one-shot nature. Most of the resulting possibilities for the support of current job and production planning have not yet been utilised. The reasons for this situation are manifold. For instance, the major effort and expense necessary for the construction and adaptation of simulation models are very often cited as a barrier to permanent application. Furthermore, the simulated production plants and logistic systems are subject to highly dynamic conditions. This fact is, of course, taken into account by simulators, but is limited to previously specified behaviour within a restricted parameter field. On the other hand, the parameters encountered during real operation are subject to considerably more severe and unpredictable fluctuations, as a function of the jobs to be performed. Consequently, the possibilities of adapting the simulation model must be designed and matched to allow employees to generate new simulation experiments for testing alternative scenarios even if they have not been trained in the application of the simulator.

Furthermore, the lack of confidence in the simulation and the results thus obtained is considerable, especially in the case of small and medium-size enterprises (SME). Precisely at these companies, therefore, inadequate methods and equipment are frequently still employed for operative job planning, and the corresponding efficiency is thus insufficient.

The objective of the working group, “Open Digital Factory” (ODF) in the Sim-Serv project is to find a way of providing an efficient tool concept and thus substantially improving job and production planning, especially for SME. For this purpose, special emphasis is placed on networking of advanced planning and scheduling (APS) systems with material flow simulators. In this context, concepts must be developed and defined for interfaces and standards. The basic orientation of developmental activities in the future and the advantages expected as a result of such coupling are described more exactly in the following.

2. State of the art and classification of the project

The term “digital factory” has been a frequently used catchword at industrial companies for quite some time. The definitions applied in this context are as numerous and diverse as the requirements which are imposed on the digital factory. With the aim of standardising the specialised terminology, a special committee has been active in the *Verein Deutscher Ingenieure* (VDI) (German Association of Engineers) for about two years. The purpose of this committee is the preparation of a catalogue of basic principles for Guideline 4499 to be published in the foreseeable future. In this conjunction, the term ‘digital factory’ is currently defined as follows:

“The digital factory is the generic term for a comprehensive network of digital models, methods, and tools – including simulation and 3-D / virtual-reality visualisation –, which are integrated by a continuous data management system.
Its purpose is the integrated planning, evaluation, and continuous improvement of all essential processes and resources of the factory in combination with the product.”

At present, the developmental activities associated with the digital factory are still focussed primarily on the planning of factories, production plants, new logistic systems, etc. From the preceding definition, however, it is clearly evident that the operation of production plants and factories will also be supported to an increasing extent with the use of these digital tools in the future.

Two advanced digital factory concepts are currently offered by Delmia and Tecnomatix; a few solutions from other companies are also available on the market. All of these approaches are based on a similar concept: The various software tools are mutually networked by a central data management system which constitutes the core of the integrated solutions incorporated in the product spectrum of the respective software supplier. The object of the endeavour is to ensure that all planning results are always completely up-to-date and are available to the authorised users at all times. With these concepts, a virtual-reality system constitutes the platform for high-end visualisation of the planning results and thus facilitates interdisciplinary communication among various experts despite differences in specialised terminology [1]. In figure 1, the architecture of the digital factory is represented diagrammatically as a draught version.

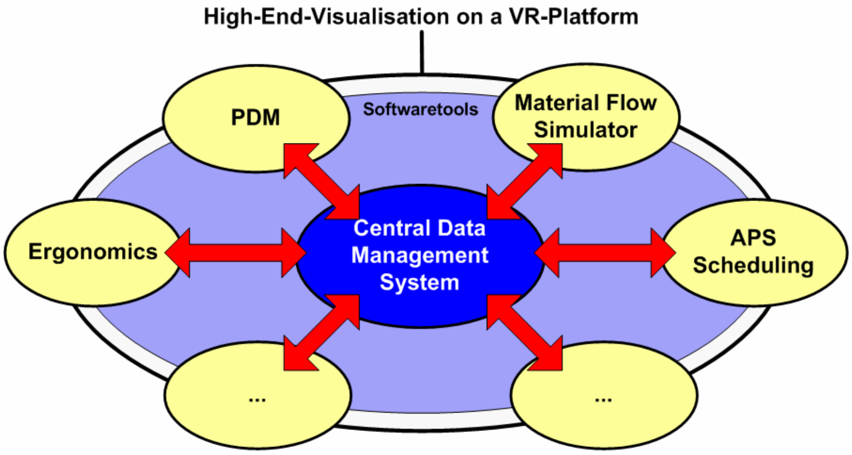

Figure 1: Diagrammatic representation of possible architecture for the digital factory

However, the reality of the digital factory is still far removed from the solution which is outlined here. The implementation of the concept involves a multiplicity of problems which have not yet been solved [2]. Among other difficulties, the existing organisational structures and the processes currently applied at the companies are not suited for achieving the objectives of the digital factory. A typical drawback of the software currently available for the digital factory is the fact that most tools have been developed only for a single, highly specialised application. Furthermore, a solution to the interface problems which result from the use of different data formats cannot be expected in the foreseeable future. From an economic standpoint, however, an especially critical question concerns the extent to which the digital factory is really necessary at a given company, that is: “How much digital factory do you actually need?” The answer to this question will always depend on the respective company, its product assortment, production plants and philosophies, etc. and therefore cannot be formulated in a generalised manner [3].

As a matter of principle, the problems just described should be approached by designing the software with a sufficiently open structure to allow docking of another tool or implementation of a company-specific application at any time. For this purpose, however, substantial portions of proprietary program codes and data formats would have to be freely accessible. Of course, software suppliers would hardly be willing to accept a solution of this kind, since they fear the loss of know-how as an inevitable side-effect of such a procedure. Consequently, networking of the various programs will have to be accomplished by other means. The concept of the open digital factory has been derived from these considerations. The corresponding solution should permit the integration and application of various planning results through the definition of standards and interfaces, but without specification of particular tools; that is, an open structure is to be generated indirectly. However, since the field of research necessary for such a consideration is much too extensive, the investigations by the ODF Working group should restricted to a partial aspect of the digital factory, which is explained in greater detail in the following.

Although the developmental work for the digital factory is currently still concentrated on the planning process, increased emphasis will be placed on controlling and planning of jobs and production in the future. For this purpose, the entire supply chain must also be considered in more detail. In this context, advanced planning and scheduling systems are becoming more firmly established for planning of the operative business and for coordination of the supply chain at the companies. These systems are essentially extensions of the classical enterprise resource planning systems (ERP), which perform the function of a data backbone in the case of APS. In this manner, the limited resources and the shortages in production can be taken into account in the planning process at present. Simultaneous, shortage-oriented planning is thus possible in the functional departments for materials management, procurement, production, transport, sales, and distribution. Plans which result only from ERP cannot be implemented in reality because the resources are assumed to be unlimited in the ERP algorithms [4].

However, a weakness of the APS systems currently available on the market is the failure to adequately support the decisions reached on the structure and resource configuration of supply chains within the scope of the supply chain configuration (SCC) [5]. Consequently, the more sophisticated planning algorithms of APS require a better understanding of the sequences and of the dynamic behaviour of the overall system comprising the production and supply chain. For obtaining the corresponding data for the shortage behaviour of production as well as for better understanding the overall system, material flow simulation has proved to be a very useful tool [6].

For constructing a simulation model, expert knowledge is still a necessity. In conducting a simulation study, however, a major portion of the time is consumed for determining and processing all of the data which are necessary for parametrising the model and for entering these data into the model. At present, many simulators provide interfaces which allow highly automated input of new parameters [7]. Thus, the model can also be used by employees who do not have any experience with simulation techniques. This feature opens new possibilities for the application of simulation in plant operations at factories. If all necessary ERP and APS data are available, and if the model is parametrised automatically, planning results from the systems can be checked immediately by means of the simulation. Moreover, in the event of plant failures or supply shortages, or both, emergency scenarios can be run, and decisions can be reached for optimising the solution on the basis of the simulation results. For this reason, the development of the basic principles for networking of APS and material flow simulation should constitute the major task of the ODF working group. In conclusion, the theoretical architecture and the associated partial aspect of the digital factory are illustrated in figure 2.

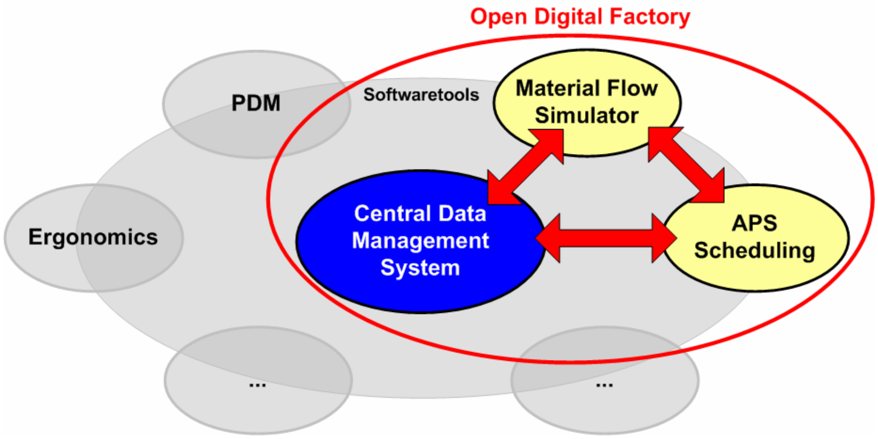

Figure 2: Sectional view of the project, "Open Digital Factory"

3. Concept for coupling of APS and material flow simulation

Not only the vision of the digital factory, as currently propagated by the automotive industry in particular, but also the ODF concept is based on a central data management system. In this case, too, a stepwise extension to include additional applications should thus be possible in the future. However, the fundamental problem is to determine which functions will be necessary for realising the ODF concept. For the partial aspect of the digital factory considered in the project, the following requirements are thus imposed on the material flow simulator:

The possibility of generating models automatically is an absolute prerequisite. External control of the material flow must also be possible. For avoiding the dependence on expert knowledge for parametrising of the model, convenient user interfaces should be provided. The idea of developing a kind of cockpit or control station equipped with such an interface is thus a logical approach. All data must be transmitted without difficulty by means of a data base and corresponding interfaces; the simulation runs must be evaluated automatically as far as possible and presented in appropriate formats. In addition, it should be possible to allow interaction of the simulator with APS programs, such as SAP APO, SimAL – Logomate, Inform, and Precator, even during the simulation. Joint maintenance of data should ensure the availability of the appropriate master data, such as production spectrum and article data, as well as machine, transport, and personnel data, etc. On the basis of these data together with information on the process sequences, strategies can then be tested for optimising material flow, machine utilisation, and job management. Moreover, the system should allow monitoring of regular operation as well as a comparison with the simulation. For achieving this objective, interfaces, standards, and, if appropriate, transfer formats must be developed for the data transfer to allow communication among the various tools in a kind of "telegram" style.

4. Advantages of coupling APS and material flow simulation

For illustrating the advantages offered by the aforementioned concept of the ODF working group, an example is briefly outlined here. In the present case of production in a workshop, the material flow is realised with the use of fork lifts. The material flow is defined as follows:

- At job start, the workpieces are withdrawn from the warehouse and transported to the first machining station.
- After completion of the first process step, the workpiece is either sent to a buffer for intermediate storage or transported to the next machining station as specified in the job plan.
- After the final process step, the finished workpiece is sent to the Shipping Department and packaged, provided that sufficient capacity and the appropriate packaging material are available. Subsequently, the finished product can be stored or shipped immediately, if a truck / lorry is available.

In figure 3, the structure of the production plant in the example is represented diagrammatically with the company-internal networking and coupling into the supply chain.

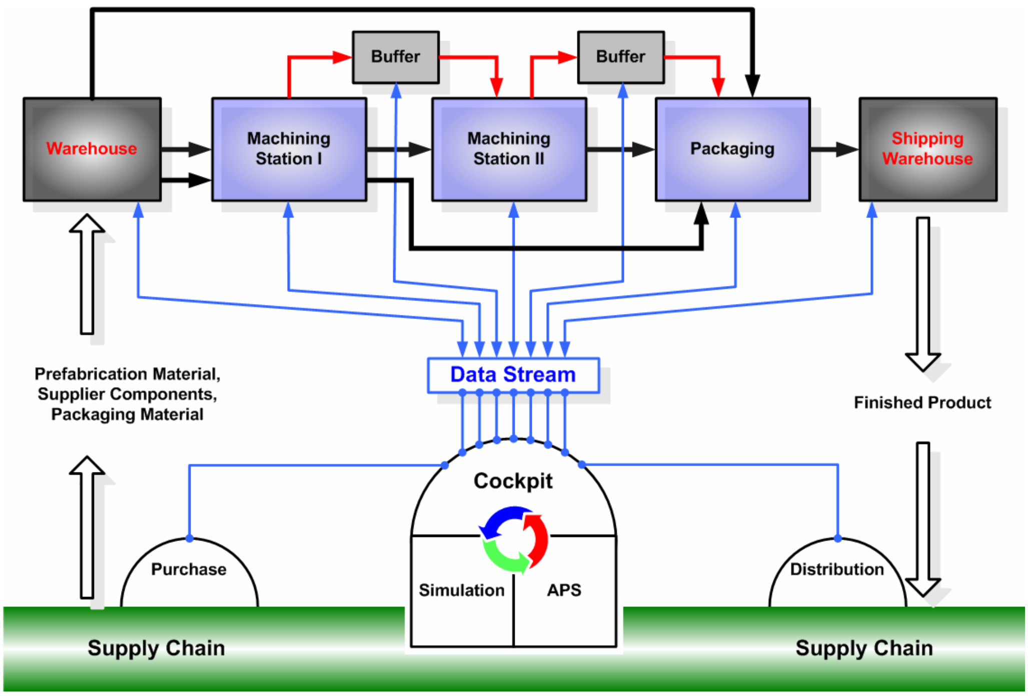

Figure 3: Diagrammatic representation of coupling

As can be seen from the figure, a certain number of alternatives exist even with this simple sequence. For the very implementation of this production scheme, an understanding of the dynamics specific to this system must first be generated. For this purpose, a simulation model can be developed and parametrised with the use of the planning data. From the initial simulation experiments, in turn, the necessary input is obtained for supplying fundamental information on availability of resources, shortages, etc. to the APS. During the further operation of the plant, the simulation model is immediately accessible by way of the coupling for generating 'What-If' scenarios in the event of irregularities in production or malfunctions in the supply chain. For this purpose, however, the operational data must be permanently determined. Besides elementary information, such as specifications on 'when which job is to begin or has been completed', information concerning unplanned stoppages and transports must also be forwarded to the APS. For instance, if the necessary packaging material is not delivered in time, or if an individual machine fails, emergency scenarios can be generated immediately, and alternative procedures can be determined for avoiding or minimising a plant shut-down. Especially for allowing flexibility in production, an appropriately modified simulation model can provide new data for the algorithms of the APS for reconfiguration of the plant or for a drastic product change. The efficiency is thus increased, not only in pure job scheduling, but also in interdepartmental logistics. As a result, the operation is optimised on the job level; short throughput times are thus ensured in the long term, inventories can be decreased, and plant utilisation factors can be maximised. Furthermore, the effects on the material flow can be recognised, and appropriate preventive or corrective action can be derived from the feed-back. All of these possibilities imply an unambiguous time-saving advantage and thus considerable savings in costs during both planning and operation.

5. Special benefit of the ODF for SME

A scenario which characterises the software situation at SME can be described for the example of discrete sequence or material flow simulation. A certain number of material flow simulators, such as AutoMod, Arena, DOSIMSI-3, eMPlant, EnterpriseDynamics, Quest, SimPro, and Witness, are available on the European market. If the costs of training and hardware are neglected, purchase prices between 5 000 € and 50 000 € must be expected for the acquisition of these simulators. If these costs in themselves already present an obstacle to the introduction of simulation tools at SME, the lack of the necessary operating personnel proves to be a nearly insurmountable barrier. Even if an employee can be assigned to this task and successfully trained to use the necessary software, the lack of experience cannot be compensated, and the quality of the initial simulation studies is therefore questionable. Consequently, the services of a simulation expert are almost an absolute prerequisite for the project, and this requirement results in additional cost. Furthermore, simulation studies are frequently conducted as one-shot optimising projects at the companies. If this aspect is also taken into account, it is obvious that economical use of simulation software is feasible only if a further application of the tool is possible.

As can be seen from the simple example of material flow simulation, comprehensive integration of all planning and operational software tools of the digital factory is obviously not a viable solution for small and medium-sized enterprises. For one thing, complete digitalisation all the way to the application of virtual-reality tools is still more a vision than a reality at present; furthermore, such an objective rigorously exceeds the budget and available personnel resources of these companies. Since they do not have their own planning departments and are often not equipped with adequate tools for job scheduling, these companies run the risk of missing their connection with the innovations of the digital factory. Nevertheless, existing customer-supplier relationships give rise to the necessity of applying new tools for planning and controlling plant operations. For implementation, this could be accomplished in the form of a “cockpit” or control station which couples the two applications of material flow simulation and APS.

However, why does such a great advantage result from coupling of APS and material flow simulation designed in the ODF working group, especially for SME? In order to answer this question, one must be aware of the basic conditions and requirements which are imposed on production at SME. A relatively wide product spectrum or a wide range of different versions, or both, are often present at small and medium-sized enterprises. In combination with shorter product life cycles and the associated smaller production quantities, as well as fluctuations in demand, high flexibility of production must be ensured. For avoiding the accumulation of excessively large warehouse inventories, short throughput times and high machine utilisation factors must be maintained, and adequate planning is necessary, especially if the components to be supplied are very expensive or involve long delivery times, or both.

These conclusions are also applicable to large enterprises. However, large companies usually have a different product portfolio and larger quantities, as well as more completely automated, interlinked production plants which cover only a specified product range. Furthermore, the advantages due to larger production lots are directly associated with larger quantities of prefabrication materials and supplier components and thus result in lower purchase prices and more stable supplier terms. Moreover, these companies can afford to maintain larger inventories, if necessary. Hence, the planning processes for production and logistics at SME and at large companies are hardly comparable. On the other hand, however, a tool which is capable of supporting the necessary planning and of providing results whose reliability has been maximised by simulation can offer valuable assistance in the effort to enhance efficiency, especially at SME. This is clearly evident from the aforementioned factors.

As far as the costs are concerned, however, certain expenditures must always be expected. Nevertheless, the tools to be coupled constitute a worthwhile investment, since they allow permanent support of production and are therefore constantly in use. Moreover, once the appropriate personnel have been trained in the use of the tools, they develop competence in working with the programs in the long term, and the involvement of experts can thus be gradually phased out. Hence, even though a simulation expert is still required for modelling during the implementation, later modifications or redesigning of the models can be performed by the company’s own personnel. The value of this training effect should not be underestimated.

In conclusion, the results of the working group, Open Digital Factory, can be summarised as follows. For applications in the target group SME, the concept described in the preceding provides fast, tangible results, potential for optimising, and advantages for planning or restructuring of production systems as well as higher productivity in plant operations. Despite the potential indicated by the ODF approach in this project, a few critical concluding comments on the concept are also appropriate. Generally, the implementation of an APS is considerably more expensive than the purchase of a material flow simulator because of the specific changes required for the application at the company. Prices for APS systems begin at about 15 000 €, and an additional budget must be provided for the adaptations. On the other hand, the increasing necessity of applying APS at SME in the future must again be clearly emphasised. The increasing multiplicity of versions and decreasing quantities will impose more exacting demands on the flexibility of production and thus necessitate detailed planning of the sequences and manufacturing jobs. In this context, the ODF concept represents a clear-sighted approach for implementing partial aspects of the “digital factory” vision at small and medium-sized enterprises.

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