5th Conference on Production Systems and Logistics

Planning And Controlling Multi-Project Environments In Factories

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Abstract

Companies regularly undertake projects to maintain their competitiveness by adapting and embracing change. Multi-project management (MPM) is crucial for companies as it enables efficient planning and control of multiple projects, ensuring they are executed effectively and delivered on time. It helps to optimise resource allocation, minimise conflicts, and maximise overall project success, ultimately contributing to the organisation's competitiveness and growth. However, existing MPM models often lack a specific focus on the goals and requirements of the factory setting, as they aim for broad applicability. A process model should consider the project context and the interdependencies among its tasks. To address this, a new concept is necessary to efficiently plan and control a multi-project environment within a factory. To develop a suitable process model for MPM in a factory, insights from MPM practices and the production environment are required. Including those insights, project landscapes can be planned and controlled effectively and efficiently. This article provides a summary of the approach developed by the Institute of Production Systems and Logistics, with a particular emphasis on the relationships between actuating, control, and target variables.

Keywords

Factory planning; Project Portfolio Management; Resource Allocation; Process Model; Project Management

1. Introduction

Many companies face an increasingly volatile, uncertain and turbulent market environment, forcing them to make permanent adjustments and changes in their factories [1–4]. This pressure to adapt is often met with an increasing project orientation. As a result, a steadily increasing complexity and dynamism in the project landscape can often be observed. Such an environment cannot be mastered with project management approaches at the individual project level alone. It also requires a complementary multi-project management (MPM) that enables the project landscape to be designed and steered systematically and in line with the company's overall strategy [5,6]. The task of manufacturing companies is to ensure a good selection and prioritisation of suitable projects, considering the right timing in the face of numerous parallel projects to strive for the best possible allocation of resources [7,8]. A systematic, efficient and effective MPM considers the project context and the mutual influence of the projects [9].

2. Need for research

A brief overview of the topic of multi-project management and the deficits of existing approaches is given below. Also, results already published regarding this framework are summarised to give an understanding of the underlying concept of MPPC before introducing further findings and consolidating the results. First,

DOI: https://doi.org/10.15488/15246
ISSN: 2701-6277

the process model, i.e. the task view, and then the effects model, i.e. the interrelationships of the model, are addressed.

2.1 Multi-project management

According to DIN 69901-5 a project is essentially characterised by the uniqueness of the conditions in their entirety [10]. Examples of such conditions might be targets, limitations, e.g. of a temporal, financial or personnel nature or a project-specific organisation [10]. Similar projects can be interconnected within a project programme [11]. Project programmes are set up to achieve a superordinate target as effectively and efficiently as possible [12,11]. All planned, approved and ongoing projects and programmes of an organisation or division comprise a project portfolio responsible for the permanent overall planning and control of the project landscape [7]. Such a portfolio is periodically monitored and controlled by a portfolio management in charge of accepting and prioritising project applications [13]. Limited resources force companies to make an effective project selection among numerous project plans at the right time and with sensible resource allocation, which is why efficient and powerful multi-project management is needed [7]. MPM can be subdivided into tasks that can be combined into a continuous procedure as a process model [13]. The goals of planning and controlling multi-project environments include 'alignment with the targets of the organisation', 'creation of transparency and synergies' as well as 'establishment of standardised structures, processes and tools' or 'assessment of opportunities and risks' and 'initiation of countermeasures in the event of an upset [7].

2.2 Existing MPM Approaches

Several generic MPM approaches exist, for example, by SEIDL or DIN 69909-2 [14,13]. Project management can typically be divided into phases like 'Initialisation', 'Definition', 'Planning', 'Control' and 'Closure'. Necessary project management tasks are assigned to those phases and are related to each other by a temporal sequence. Such models also usually indicate the responsibilities for different tasks, often suggesting the frequency with which individual tasks are to be processed. A project landscape can be managed at an individual project level, including tasks such as project preparation or approval of project results, and at the programme and portfolio level containing operational and strategic tasks, such as managing the project portfolio. The duration of tasks at the individual project level varies depending on factors such as project type, industry, environment, and project-specific considerations. Since tasks at the individual project level follow the project life cycle, these factors also dictate the timing of task cycles at the programme and portfolio levels [13]. While common approaches to MPM enable the planning and control of multi-project environments in factories, they lack a perspective on interrelationships that could consider dependencies between projects and, therefore, cannot align the MPM tasks with the portfolio or overall factory goals [15]. According to BERGE AND SEIDL, a project portfolio summarises all planned, approved, and ongoing projects for a company or business unit [12]. NIELSEN sums up that no process model for MPM currently combines a process-oriented description with an effects model and uses its influence on company or factory goals as orientation. Without this positioning aid, conflicts of objectives cannot be resolved based on a superordinate framework model [16]. There is no holistic process model which managers in the factory can use to plan and control multi-project environments.

To close this research gap, a research project has been carried out at the Institute of Production Systems and Logistics, in which MPM approaches were enriched with insights from a systematic investigation of production planning and control (PPC). Findings were to be adapted to the context of project management, leading to a concept of multi-project planning and control (MPPC). By applying the methodology utilised in PPC models, tasks can be effectively associated with targets within the multi-project environment. For the MPPC model, the MPM approach by SEIDL was used as a primary input [17,13].

2.3 Multi-project planning and control (MPPC)

Since general MPM approaches lack abilities in supporting decision-making, findings from PPC and MPM topics were combined to create the concept of multi-project planning and control (MPPC) with a focus on factories. In this context, SCHMIDT established the Hanoverian supply chain model (HaLiMo), which comprehensively classifies PPC tasks and consolidates them within a generic framework model. This approach also considers the interrelations between PPC tasks and their respective target objectives. Using the methodology known from PPC models, tasks could be linked to targets of the multi-project environment, allowing for positioning in case of conflict of objectives.

2.3.1 Relevant tasks

To develop a task model, contents from MPM and PPC were merged into a joint knowledge base. The basis for the combination was an analogy analysis, starting from comparing project (MPM) and product (PPC) [17]. Within the framework of a deviation analysis, any gaps, different focal points and levels of abstraction were systematically uncovered. Based on the deviation analysis, combining the approaches to PPC according to SCHMIDT and MPM according to SEIDL, a comprehensive knowledge base of MPPC in the factory was developed, structured, and, where necessary, complemented by other approaches [18,13]. The result was a catalogue of generally valid tasks for MPPC from the approaches of MPM and PPC [16]. The task profiles of the MPPC in the factory were formulated. After the tasks were reviewed for redundancies and gaps, validation took place in interviews with experts in multi-project management in factories to finalise the task model. Figure 1 comprises the main tasks along the project management phases. In the figure, the different responsibilities for the main tasks can also be seen, structuring the tasks horizontally.

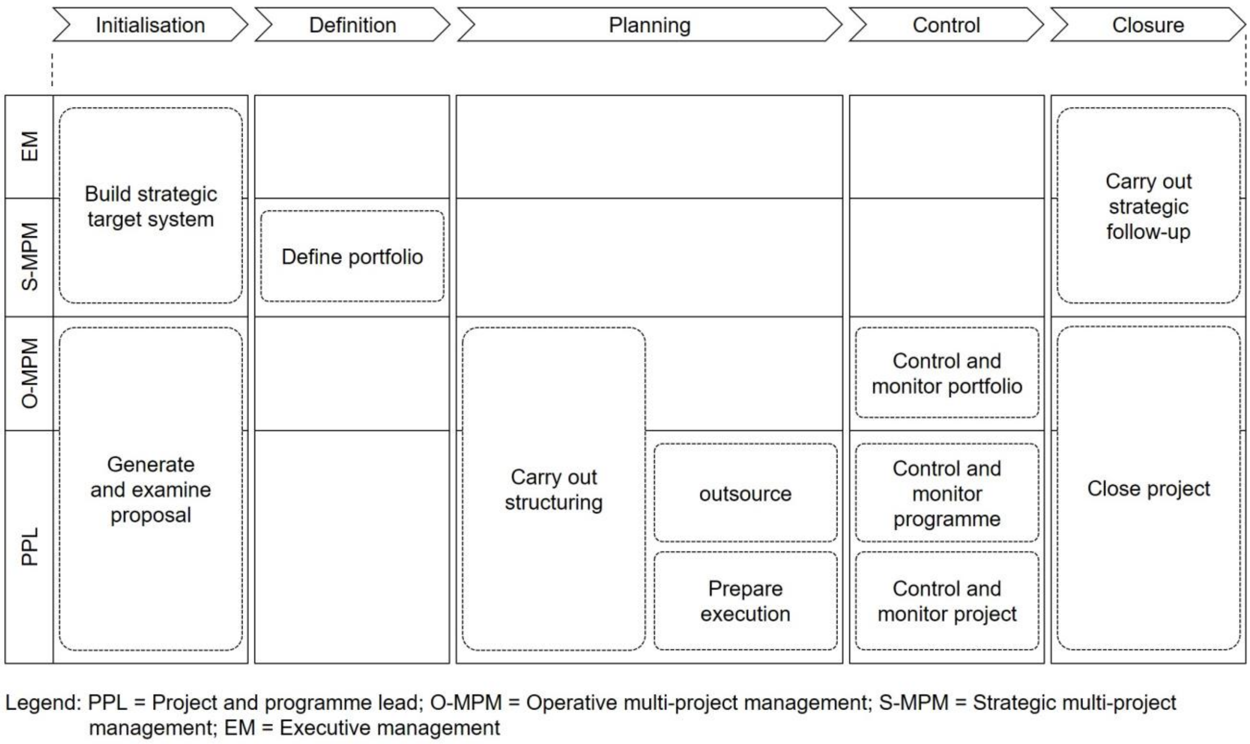

Figure 1: Main tasks of MPPC (based on [16])

2.3.2 Interrelationships

It is necessary to introduce an effects model to represent interrelationships between tasks and, ultimately, the factory targets, which consideration is elementary for effective planning and control. In PPC, the variables of the effects model are divided into actuating variables, control variables and target variables. Together the variables enable target-oriented decision-making and are crucial in target achievement [19,18]. Actuating variables can be influenced directly by fulfilling tasks and influence control variables. Target variables result from control variables and can thus indirectly be influenced by task fulfilment. By considering the effects variables, managers are enabled to make timely and professional decisions and consider interactions with other projects or company divisions. Following this logic, a catalogue of actuating and control variables is first created for MPPC. The qualitative interactions between the actuating variables are examined with the help of binary design structure matrices (DSM). Interrelationships between the actuating and control variables are described by a binary domain mapping matrix (DMM) and a causal diagram [20]. The determined actuating and control variables are shown in Figure 2.

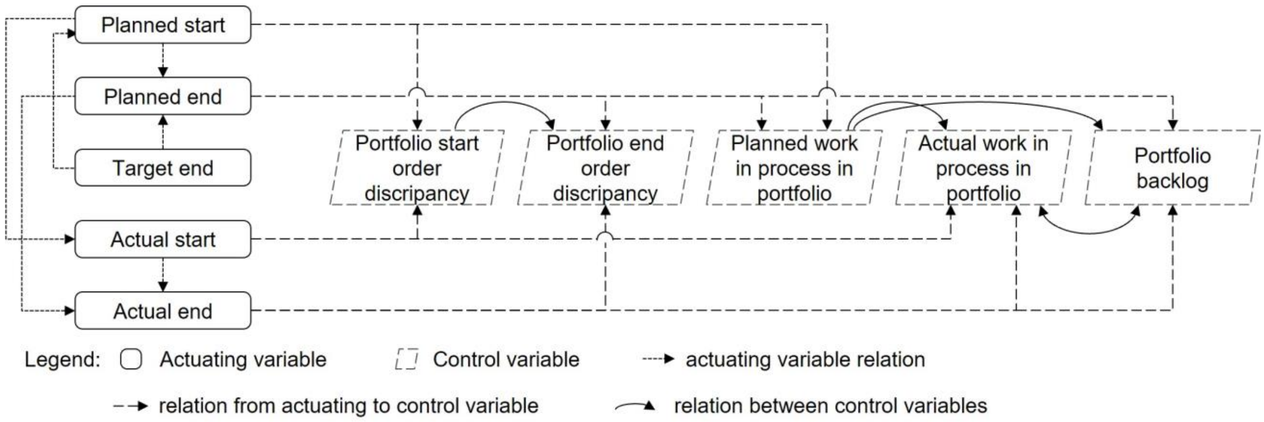

Figure 2: Actuating and Control variables with their relations (based on [16])

In addition to the relationships shown, other interactions between actuating and control variables may exist indirectly. For better readability, these relationships are not included in the figure above. An example of such indirect interrelation is the possible influence of the portfolio end order discrepancy on a future portfolio start order discrepancy. This applies, for example, if shifts in the project end order result in resource bottlenecks which in turn require a deviation from the initially planned project start order.

3. Consolidation of the MPPC process model

This section introduces the target variables to complement the part of the effects model presented so far with the control variables. In 3.1, it is shown how the target variables of a portfolio can ultimately be manipulated during processing tasks that influence control variables. Additionally, in 3.2, it is outlined how correlations between deviations in the portfolio targets and possible causes can be determined.

3.1 Target variables in MPPC and consolidation of the process model

The MPPC target variables can also be derived from the production environment by comparing PPC and MPM based on the analogy analysis mentioned above. For multi-project planning and control, five target variables can be derived from PPC approaches: portfolio utilisation, portfolio schedule reliability, portfolio throughput time deviation, portfolio transparency and portfolio delivery capability [15,16,18].

3.1.1 Target variables

In the context of MPPC, the portfolio utilisation target is introduced to show the profitability of the MPM target system. Resource availability and utilisation in projects are similar to production orders, whereby all factory components can be potential project resources. However, in contrast to PPC, the utilisation of a portfolio needs an auxiliary variable. Portfolio capacity gives a theoretical maximum to which the utilisation can be compared. This step is necessary since the available resource capacity in a portfolio can be enhanced by reducing their integration into daily business tasks. In MPPC, the target variable portfolio schedule reliability provides information on the adherence to deadlines for completed projects in the portfolio. If a project is completed within a tolerance range around the planned end date, it is considered on schedule. The use of portfolio schedule reliability is important because individual projects can have a negative impact on the rest of the portfolio due to their content and resource dependencies, both through early and mainly delayed projects. The average relative portfolio throughput time deviation is used to assess the throughput time behaviour of all ongoing projects in the portfolio. Here, the percentage deviation of the throughput time is calculated for each project in the considered period and then averaged for the entire portfolio. A positive throughput time deviation in the portfolio can be due to factors such as unavailable resources, changes in the project schedule or excessive multi-tasking. The portfolio throughput time deviation allows a statement on the actual duration in relation to the previously planned duration of the control phase, whereby systematic planning errors or disruptive influences leading to variance come to light. When analysing the throughput time deviation, it is essential to ensure positive deviations do not balance out negative deviations. Therefore, the standard deviation describes the mean spread from the expected value. In the context of MPPC, the target value of the work in process from the PPC is replaced by the target value of the portfolio transparency. The more cumulative project effort is generated by numerous or very large projects in process, the less transparent the portfolio becomes. Portfolio transparency is defined as an overview of the projects and programmes in the portfolio and is also needed for efficient cooperation between different projects, preventing multi-tasking. The target variable portfolio delivery capability provides information on fulfilling the client's desired deadlines through the target end dates of the different projects.

In general, the fulfilment of targets is made more difficult because these conflict with each other. Since portfolio utilisation is to be maximised, a high work in process benefits this target. Portfolio transparency and portfolio schedule reliability should also be as high as possible but decrease with increasing projects making up the work in process. Because the standard deviation of relative throughput time deviation increases undesirably with increasing work in process, this also advises limiting the work in process to a certain degree. The target variables conflict, leading to a positioning range in which the projects accounting for the work in process should be kept. In the positioning range, the benefits of a high portfolio utilisation concerning its saturation can be kept while mitigating the adverse effects for the other target variables.

3.1.2 Consolidation of the process model

Having described the target variables and their behaviour with increasing work in process, the effects model and the tasks of MPPC can be combined. To effectively control the multi-project environment, it is necessary to know the relationship between task processing and the effects model of portfolio management. Only based on these relationships can tasks be processed in such a way that a desired effect on the portfolio targets can be achieved through control variables. In addition to assigning the tasks to the actuating variables, they were also assigned to the project management phases: initialisation, definition, planning, control and closure. By doing so, the tasks can also be characterised in terms of planning or controlling function based on the assigned phase along the project management phases. The characterisation of the tasks allows a clear assignment to defined responsibilities provided as swimlanes. This assignment makes it possible to conclude the status of a project, especially since the project life cycle is shown along the project management phases.

Figure 3 uses the example of the task plan project structure to show how target variables may be manipulated. Through the actuating variables planned start and planned end, there is an influence on different control variables, which then affect the target variables. In this case, all MPPC targets are affected by planning the project structure, indicating that possible target conflicts may impact task fulfilment.

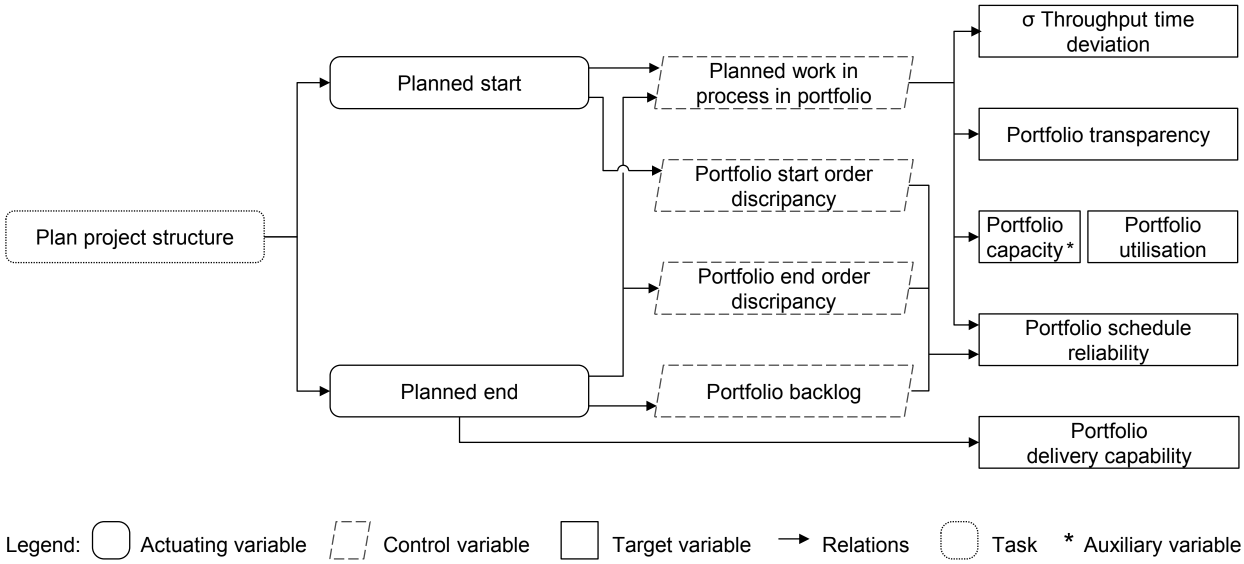

Figure 3: Example for the influence on target variables (based on [16])

How many projects to approve and, thus, where to position regarding the work in process must be determined individually for each company. It is a business decision that depends, among other things, on the opportunity costs and the priorities of the target variables. Knowing the positioning range and the conflict of targets is a prerequisite for carrying out the task in accordance with the portfolio target. The planned start and planned end, in particular, can be influenced by many tasks. This connection is based on the fact that both values will be overwritten in the course of the project management phases as soon as new information is available in a subsequent step. This observation makes it clear how important it is to have a good overview of the project in the early phases and to keep an eye on the utilisation and other target values of the portfolio. In contrast, the actuating variables actual start and actual end can only be influenced once by a task, as they are not planned values that can be overwritten but events that actually occur on a singular occasion. The target end is an actuating variable with a special status, representing the customer's wish for project completion and only providing information about the portfolio delivery capability compared to the planned end. By planning start and end dates for a project and by actually realising them, it is possible to influence the control variables, as shown in Figure 2, steering the target fulfilment.

3.2 Determining causes for deviations regarding portfolio targets

Since one aim is to ensure effective use of the process model, it is crucial to go beyond describing the interrelationships and to indicate causes for possible deviations from portfolio targets. In particular, users with little competence in multi-project management may otherwise be able to plan a portfolio but not know how to take the necessary countermeasures in the event of deviations. To prevent this, cascades of possible causes are introduced to provide assistance. Figure 4 shows such a cascade of effects based on the example of portfolio schedule reliability.

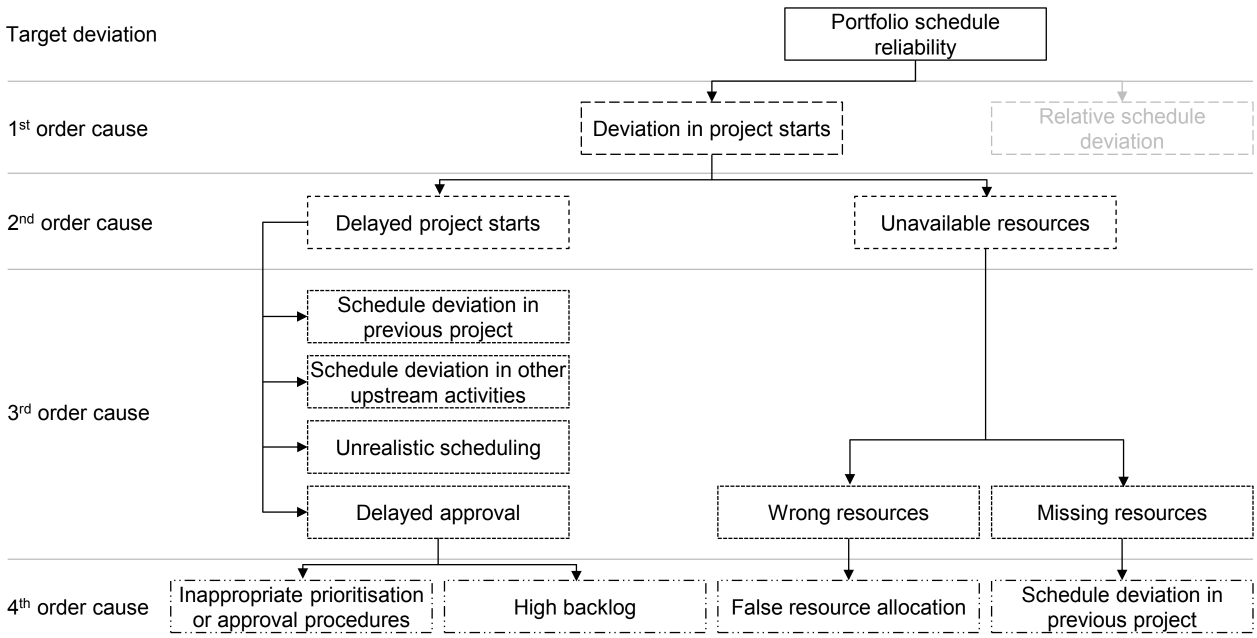

Figure 4: Causes for target deviations by the example of portfolio schedule reliability

The causes for deviations can be divided into different orders. A first-order cause directly affects the target variable and is affected by one or several second-order causes. For example, deviations in portfolio schedule reliability may be caused by a deviation in project starts (1^{st} order) caused by unavailable resources (2^{nd} order). This might have been the case because the wrong resources (3^{rd} order) were provided, resulting from a false resource allocation (4^{th} order). Even though this example may appear self-explanatory, it is essential to demonstrate these relationships, as causes can be present in a wide variety, with significant variance, and in significantly more complicated relationships. Taking into account causes for deviations in target fulfilment allows for a holistic observation of a project landscape, from task descriptions to causes of target deviations.

3.3 Validation of Findings

After building the process model of MPPC, the validation aimed to examine the results in terms of applicability and practicality. The process model was validated through interviews with experts from different backgrounds. A project portfolio manager working in the biopharmaceutical industry and the managing director of a company from the field of project management consulting and software development supported the validation process. Taken together, these experts were able to bring in the experience of many different approaches and portfolio conditions. Both were involved at the beginning of the project, after establishing the task profiles and again after developing the effects model to reflect on the intermediate status, ensuring a legitimate base for further steps. During these validation phases, the process model was analysed in comparison to the existing conditions, metrics and processes within the companies.

During the first validation phase, the developed MPPC task profiles were discussed in short workshops concerning their practicality and degree of detail. An example of an updated task refers to the definition phase. That task initially described the determination of portfolio cost behaviour, which was then adapted to focus more on the resources behind the costs. Discussing the task model within the validation process revealed that the execution of some tasks may differ according to the company's size, industry or business model. Therefore, the tasks kept in the process model were designed and checked to fit a broad application. Based on this validated interim status, the effects model was then developed. Subsequently, the whole process model was validated with the experts, this time focusing on the effects model and the decision points of the task processing. An example of input from the second validation stage is the idea of dividing the target variable portfolio transparency into qualitative and quantitative factors since not every project can be tracked in the same way. As a result of the discussions during validation, minor additions and adjustments could be made to both the tasks and the effects model. However, even though the validation took place considering different companies, portfolios and areas of responsibility, the validation results cannot guarantee the usability of the process model for any manufacturing company and its factories. Further studies need to be conducted to assure further applicability.

4. Conclusion and Outlook

Within the scope of developing a model for the planning and controlling of multi-project environments in factories, the contents of PPC and MPM were merged based on an analogy examination. It was possible to derive generally valid tasks and an effects model from its joint knowledge base, which then had to be consolidated. The entire process model allows decisions in a portfolio to be made considering overall portfolio targets by connecting tasks with the actuating variables of the effects model. Possible causes for target deviation have been identified to assist in the case of failing to reach target fulfilment. As part of developing the process model, a fast lane for more efficient planning and control of individual projects along the project management phases was also introduced [21]. For this purpose, a project categorisation was described concerning the degree of novelty. Based on that categorisation, statements can be made about which tasks have the potential for standardisation. More efficient planning and control of these project types could ultimately free up resources for urgent or high-priority projects. The validation of the developed process model successfully confirms the basic statements on the tasks and interdependencies of the MPPC, as well as its practical relevance and suitability.

Additional validation cases may be examined in the future, further evaluating the model's applicability. There is a need for research on the quantitative modelling of the presented interdependencies. In particular, the mathematical modelling of the interrelationships between control and target variables is challenging since the mostly non-linear interrelationships require extensive modelling effort. Building on the existing analogy, further studies comparing the control panel of PPC and the project management office of MPM are feasible for the future. The cause-effect relationships could also be examined more closely for the targeted control of the portfolio to improve the achievement of the target variables.

Acknowledgements

The authors kindly thank the German Research Foundation (DFG) for the financial support to accomplish the research project "Entwicklung eines Prozessmodells der Multiprojektplanung und -steuerung in der Fabrik (MPPS-Fabrik)" (project number 439916044).

References

[1] Lanza, G., Nyhuis, P., Fisel, J., Jacob, A., Nielsen, L., Schmidt, M., Stricker, N., 2018. Wandlungsfähige, menschzentrierte Strukturen in Fabriken und Netzwerken der Industrie 4.0 (acatech Studie). Herbert Utz Verlage, München.

[2] Mack, O., Khare, A., 2016. Perspectives on a VUCA World, in: Mack, O., Khare, A., Krämer, A., Burgartz, T. (Eds.), Managing in a VUCA World. Springer International Publishing, Cham, pp. 3–19.

[3] Schenk, M., Wirth, S., Müller, E., 2014. Fabrikplanung und Fabrikbetrieb: Methoden für die wandlungsfähige, vernetzte und ressourceneffiziente Fabrik, 2., vollst. überarb. und erw. Aufl. ed. Springer Vieweg, Berlin, Heidelberg, 832 pp.

[4] Wiendahl, H.-P., Reichardt, J., Nyhuis, P., 2014. Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten, 2., überarb. und erw. Aufl. ed. Carl Hanser Verlag, München Wien, 35469 pp.

[5] Aurich, J.C., Barbian, P., Naab, C., 2005. Multiprojektmanagement in der projektorientierten Produktion: Gestaltung und Lenkung der Projektlandschaft in der Produktion. wt Werkstattstechnik online 95 (1/2), 19–24.

[6] Hiller, M., Klusch, M., Monjé, M., 2001. Multiprojektmanagement als Führungsinstrument der Zukunft. ZWF 96 (6), 317–321.

[7] DIN, 2013. Multiprojektmanagement – Management von Projektportfolios, Programmen und Projekten - Teil 1: Grundlagen. Beuth Verlag, Berlin.

[8] Kunz, C., 2007. Strategisches Multiprojektmanagement: Konzeption, Methoden und Strukturen, 2nd ed. Deutscher Universitäts-Verlag GWV Fachverlage GmbH, Wiesbaden, 312 pp.

[9] Rabl, W., 2013. Projektmanagement, in: Kleinaltenkamp, M., Plinke, W., Geiger, I. (Eds.), Auftrags- und Projektmanagement. Mastering Business Markets, 2., vollständig überarbeitete Auflage 2013 ed. Springer Gabler, Wiesbaden, pp. 301–381.

[10] DIN, 2009. Projektmanagement – Projektmanagementsysteme - Teil 5: Begriffe. Beuth Verlag, Berlin.

[11] Kuster, J., Huber, E., Lippmann, R., Schmid, A., Schneider, E., Witschi, U., Wüst, R., 2011. Handbuch Projektmanagement, 3. Auflage ed. Springer-Verlag Berlin Heidelberg, Heidelberg, Dordrecht, London, New York, 460 pp.

[12] Berge, F., Seidl, J., 2009. Programmorientierung, in: Gessler, M. (Ed.), Kompetenzbasiertes Projektmanagement (PM 3). Handbuch für die Projektarbeit, Qualifizierung und Zertifizierung auf Basis der IPMA Competence Baseline Version 3.0, vol. 4, 1. Auflage ed. GPM Deutsche Gesellschaft für Projektmanagement e.V, Nürnberg, pp. 2181–2204.

[13] Seidl, J., 2011. Multiprojektmanagement: Übergreifende Steuerung von Mehrprojektsituationen durch Projektportfolio- und Programmmanagement. Springer-Verlag, Berlin, Heidelberg.

[14] DIN, 2013. Multiprojektmanagement – Management von Projektportfolios, Programmen und Projekten - Teil 2: Prozesse, Prozessmodell. Beuth Verlag, Berlin.

[15] Nielsen, L., Klausing, P., Nyhuis, P., 2021. Towards a Target System to Incorporate Sustainability in Multi-project Management in Factories., in: , Research on project, programme and portfolio management. Integrating sustainability into project management. Springer International Publishing, pp. 9–23.

[16] Nielsen, L., 2020. Prozessmodell für Multiprojektmanagement in der Fabrik. Dissertation, 231 pp.

[17] Hook, J., Nielsen, L., Nyhuis, P., 2021. Introduction Of A Concept For Planning And Controlling Multi-Project Environments In Factories.

[18] Schmidt, M., 2018. Beeinflussung logistischer Zielgrößen in der unternehmensinternen Lieferkette durch die Produktionsplanung und -steuerung und das Produktionscontrolling. Habilitationsschrift, Hannover.

[19] Lödding, H., 2016. Verfahren der Fertigungssteuerung: Grundlagen, Beschreibung, Konfiguration, 3. Auflage ed. Springer Vieweg, Berlin, Heidelberg, 664 pp.

[20] Hook, J., Nyhuis, P., Nielsen, L., 2022. Einfluss des Multiprojektmanagements auf Fabrikziele/Influence of multi-project management on factory goals – Developing a process model for planning and controlling multi-project environments in factories. wt 112 (04), 216–220.

[21] Hook, J., Nielsen, L., Nyhuis, P., 2022. Introducing a Fast Lane to Multi-Project Environments in Factories to Focus on Digital Transformation, in: Kim, D.Y., Cieminski, G. von, Romero, D. (Eds.), Advances in production management systems. Smart manufacturing amd logistics systems : turning ideas into action : IFIP WG 5.7 International Conference, APMS 2022, Gyeongju, South Korea, September 25-29, 2022, proceedings, vol. 664. Springer, Cham, Switzerland, pp. 157–164.

Biography

Justin Hook (*1994) studied industrial engineering with a focus on production technology at Leibniz University Hannover and University of Southern Denmark. He works as a research associate in the field of factory planning at the Institute of Production Systems and Logistics (IFA) at the Leibniz University Hannover since 2020.

Dr.-Ing. Lars Nielsen (*1986) studied industrial engineering and management at the University of Bremen, University of Cape Town and Technical University of Berlin. After working for two years as specialist for multi-project planning and control he started as a research associate at the Institute of Production Systems and Logistics (IFA) at the Leibniz University Hannover. After finishing his doctorate in engineering he worked as senior project leader in the FMCG industry as well as a team leader for project portfolio management at a leading reinsurer.

Prof. Dr.-Ing. habil. Peter Nyhuis (*1957) studied mechanical engineering at Leibniz University Hannover and subsequently worked as a research assistant at IFA. After completing his doctorate in engineering, he received his habilitation before working as a manager in the field of supply chain management in the electronics and mechanical engineering industry. He is heading the IFA since 2003.