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Production Ramp-up on learning islands

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Abstract

The increase in product variance and shorter product lifecycles result in higher production ramp-up frequencies and promote the usage of mixed-model lines. The ramp-up is considered a critical step in the product life cycle and in the automotive industry phases of the ramp-up are often executed on separated production lines (pilot lines) or factories (pilot plants) to verify processes and to qualify employees without affecting the production of other products in the mixed-model line. The required financial funds for planning and maintaining dedicated pilot lines prevent small and medium-sized enterprises (SMEs) from the application. Hence, SMEs require different tools for piloting and training during the production ramp-up. Learning islands on which employees can be trained through induced and autonomous learning propose a solution. In this work, a concept for the development and application which contains the required organization, activities, and materials is developed through expert interviews. The results of a case study application with a medium-sized automotive manufacturer show that learning islands are a viable tool for employee qualification and process verification during the ramp-up of mixed-model lines.

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Keywords: Production ramp-up; learning island; training; qualification

1. Introduction

Planning and commissioning of production systems is an essential part of ramp-up management [10]. Hence, the automotive industry often verifies processes and systems in separated pilot lines or pilot plants [11, 17]. Processes are validated and employees receive training in these dedicated production systems, without affecting the production of other products on the mixed-model line. Employee qualification is a second important part of ramp-up management [10], especially for small series production, in which the employees are the main source of information [7]. Qualification occurs through induced (deliberate experimentation) or autonomous learning (through production experience) [19] and in SMEs mainly on the production line, during the ramp-up.

The application of dedicated ramp-up factories and lines for process validation and employee qualification is limited to larger companies, as the financial funds often exceed the capacity of SMEs [21]. Other tools and methods exist [6], however, are often not described in greater detail or lack applicable concepts for practitioners. Learning islands propose a solution for the described ramp-up challenges, as they enable induced and autonomous learning for employee qualification [3] and facilitate process verification.

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2. Conceptual framework

The ramp-up is the change from development phase to production phase and starts with the release of pilot production and ends with achieving a stable production at the desired capacity [2, 18]. As many SMEs [2] and corporations struggle with the production ramp-up [6] several concepts have been developed. The resulut of the research project “fast ramp-up” are five fields of action [10] which have been extended by several authors and can be grouped into the categories organization, activities, and materials [8].

2.1. Ramp-up organization, activities and materials

The ramp-up organization is both the organizational and operational structure required for the ramp-up [4]. Different organizational structures can be combined depending on the level of innovation and complexity for each ramp-up as well as the company size and the ramp-up frequency [6]. The operational structure for ramp-ups are processes that detail the tasks and activities for each entity within the organizational structure [6].

Activities for the production ramp-up are [10, 1]: Planning and controlling, development of ramp-up robust production systems, change management, cooperation (e.g. with suppliers) and usage of reference models, knowledge and personnel management, risk management and strategic project selection.

For the pilot production and zero-series, during which large quantities with conditions close to the serial production are manufactured and final production tools are used [17], the physical materials (e.g. raw materials, tools and fixtures) need to be developed, procured and commissioned.

2.2. Learning islands

Learning islands are a tool for induced and autonomous learning [13] and are known for the training of apprentices in the German dual education system [3]. They are situated within the production and are used for employee training and development [13]. The employees receive more time to perform their tasks and are supported by learning materials and visualization tools [3].

3. Methodology

The aim of this research program is the development of a concept for learning islands, which assists SMEs during the production ramp-up of small-series on mixed-model lines. To achieve this expert interviews were conducted with partners from five different companies that either utilize learning islands or mixed-model lines. The goal of the expert interviews was to identify characteristics and best practices of the organization, activities, and materials for learning islands and the ramp-up of small series, as most of the existing ramp-up literature is focused on high volume industries [18]. The concept was then developed and evaluated through a case study application in a sixth company.

In total nine managers and professionals of five companies (A-E) working in ramp-up related departments or learning islands were interviewed. The expert interviews were conducted semi structured [12] and the transcripts of the interviews were analyzed using a coding technique which was deduced from the conceptual framework.

All five interviewed companies utilize mixed-model lines, three are producing small-series and three are using learning islands. Due to the specific functions of the experts, only ramp-up or learning island specific answers where provided, except for company B, in which the experts are involved in the ramp-up and in the development of learning islands. Thus, the interviews provide two results, one showing characteristics for the production ramp-up of small series and one for the development and application of learning islands.

Based on the expert interviews with company A and B, ramp-ups of small series are conducted similar to high volume industries. However, company B points out, that the formal change management is only conducted “downstream” (from engineering to the shop floor), upstream changes are managed informally. Also, both companies do not produce pilots or zero-series but instead produce customer orders immediately after the development phase. Even though both companies want to utilize interoperable planning tools, the expected implementation and maintenance efforts prevent this. The interviews with the experts of company B, C, D, and E provide insights into the development and application of learning islands. They are used for training employees on existing products and processes as well as for the training on pre-series products (C). The operational structure of all learning islands follows defined learning island processes which are managed through distinct functional units that provide either expert knowledge on products and processes (C, E) or methodological support (D). The knowledge management bases on qualification and training models and is ensured through lessons learned workshops. Also, learning islands are used to qualify multiplicators, which should spread their learnings. On the learning islands models, pre-series (prototypes, pilots, zero-series) and customer orders are built for training.

4. Concept development

Based on the results of the expert interviews and the existing ramp-up literature the following concept for the production ramp-up on learning islands was developed.

4.1. Ramp-up organization

The expert interviews (and several case studies, e.g. [17]) show, that practitioners apply traditional project management approaches based on the product development process. As the development and application of learning islands also follow defined processes these are integrated into the ramp-up. Learning islands are regarded as an own production system and the learning island life cycle thus contains (based on the production system lifecycles [20]) the steps (re-)planning, realization/adaptation, operation, and dismantling.

For the development of the organizational structure for learning islands a new method is defined based on the results of the expert interviews: Companies with a low ramp-up frequency and a low variety of trainings should integrate learning islands into the ramp-up organization. The primary structure, which defines who should lead the trainings for each ramp-up, depends on the level of changes to the product and the production system. With increasing ramp-up frequency the learning islands should be managed permanently by an expert team and with increasing training variety a methodological support team for the primary structure is suggested (see Fig. 1).

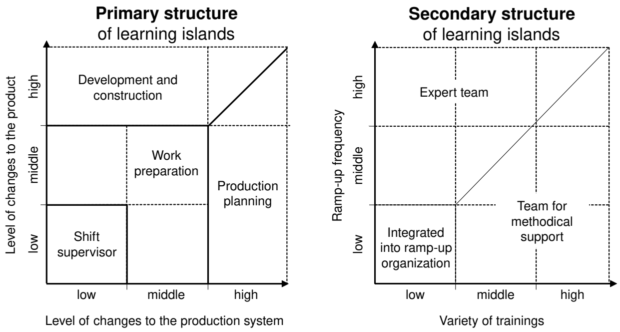

Fig. 1. Scematic for organizational structures of learning islands

4.2. Ramp-up activities

The interviews show that small series ramp-ups are managed through process models, milestones and quality gates. Thus, the model of Böning and Sejdic [2] is extended by the learning island life cycle (see operational structure 2) and the targets of the learning islands are integrated into the milestones and quality gates.

Learning islands function as a model of the production system and support the development of ramp-up robust production systems through process verification and should be ramp-up robust themselves. Based on the factory planning process [20] the planning domains ”objectives” and ”factory and production logistics”, as well as the planning levels ”work center” and ”segment” must be planned. The first process step is the setting of objectives, which includes to model the production system. For the selection of the scope and the model accuracy a cost-benefit analysis between more precise statements on process maturity and increasing effort and costs during the planning, realizations and operational phase has to be made. Depending on the objectives of the learning island the new product, new processes or entire parts of the factory system can be modeled and piloted. During the concept planning phase changeability (e.g. modular structures) for the iterative usage must be considered. For the detailed planning phase, company D recommends considering leasing new equipment, especially if new technologies are tested. Digital planning tools can support the planning of ramp-up robust learning islands, if they are used for the actual production planning as well.

The interviews show, that the standardized change management processes and iterative development processes are applied in industrial practice, but defined upstream change management processes are lacking (see Sect. 3). As learning islands enable the identification of changes, a software tool is implemented, where the ideas are first collected, categorized and assigned to responsible departments (e.g. industrial engineering).

To manage changes across company lines, the interviewed companies use standardized communication control loops for supplier integration. Formalized data management tools in cooperation with suppliers are not applied during the ramp-up of small series (see Sect. 3).

Knowledge and personnel management is an essential part of this concept, as training employees for the required cycle time is one of the core objectives for mixed-model lines. This requires optimum decision-making quality in the production ramp-up through knowledge transfer and an uniform target system [5]. To this end, a training and qualification model was developed which enables early capacity planning by means of a phase plan.

For risk management a risk portfolio in combination with a failure mode and effect analysis is selected. The risk assessment can be carried out by a subjective assessment or method-based, e.g. through a sensitivity analysis or a pairwise comparison [7]. While learning islands are an instrument of risk management, with which risks are discovered and countermeasures validated before the SOP, the (business) risk of one must also be considered.

The interviews show that ramp-up related departments are often not involved in the strategic project selection and deal with several ramp-ups simultaneously. According to the experts of company A the incremental ramp-up of different variants promises improvements on mixed-model lines and is thus integrated into the concept.

4.3. Ramp-up materials

At each stage of the ramp-up, materials are processed and components, assemblies, and finished products are manufactured. While the pilot series products of the automotive industry are only used for testing, training or trade fairs [11], in small series production customer products are already being manufactured after the development phase (see Sec. 3). For this concept, it is therefore assumed that learning islands are also used to manufacture customer orders. Through order triggering the processes to the suppliers are checked and can be addressed in the implemented control loops (see Sect. 4.2). Likewise, the internal processes (production orders, logistics processes [15]) are also validated. Quality assurance is represented as a cross-sectional function and is important as production is carried out for the first time under near-series conditions and customer orders are produced. How detailed the production on the learning island represents the later production system depends on the type of learning island. To increase the model accuracy, additional materials must be made available, which increases the planning and operating effort. The least effort is represented by the ”product learning island”, for which the components of the product, materials for collecting change ideas and a central point for regular communicating must be provided. For a ”product learning island”, a single learning island in workbench production is sufficient. Increased model accuracy is achieved by the ”process learning island”. Here, the assistance systems, near-series tools, auxiliary and operating resources and the material provision processes are validated. Several workplaces can be used to model the material flow and the interaction of work contents in flow production. The highest model accuracy is achieved through a ”system learning island”, in which the working environment (e.g. supporting structures) is modeled.

5. Concept application

The developed concept is verified through a case study. Therefore, a sixth company is identified which is undergoing a major transformation process [16] and a shift in production is taking place, with further vehicle lines being integrated into the variant-rich flow production.

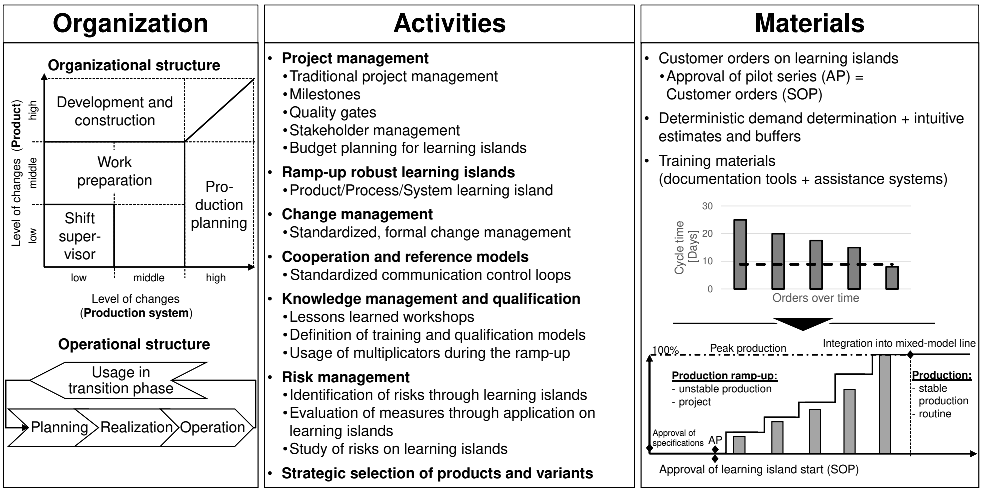

Fig. 2. Concept for the production ramp-up on learning islands

For the milestone "SOP" the additional measurements "target cycle time" and "target defect tolerance" are introduced and all vehicles produced during the case study are subsequently sold to customers and are audited and reworked to ensure the required quality. The audit results are incorporated into the milestone "SOP" through the quality gate "target defect tolerance".

During the ramp-up, a total of 122 change ideas are entered via the software tool. The majority of the change ideas relate to the assembly instructions (35%) or errors within the bill of materials (22%). Over time, the amount of identified change ideas decreases, which shows that learning islands enable the early identification of errors and enable a stable SOP on the mixed-model line. The production is already transferred to the mixed-model line after the fifth learning island product, as the targeted cycle time has been reached (see Fig. 2). The decline of the cycle time shows that the combination of induced and autonomous learning on the learning islands is successful.

6. Discussion

The results show that learning islands are a suitable tool for piloting and qualification. Assembly contents can be trained, processes verified, and materials and equipment tested. The integration of the learning island into the ramp-up reference model worked well, as many members of the organization were positive about the clear definition of goals and the specification of a target cycle time. Other parties were initially unconvinced by the learning island concept and would have preferred a direct ramp-up on the mixed-model line. It is noteworthy, that neither the experts nor the examined literature (except Renner [14]) mention stakeholder management, which is thus added to the concept (see Fig. 2). Overall, the use of the learning islands has proven successful during the ramp-up. The concept supports companies in designing an organizational structure and provides activities and materials for planning and operating learning islands. Figure 2 provides an overview of the concept for the production ramp-up of a small series, mixed-model line production on learning islands.

Next to the implications for industrial practitioners, this article also shows several research gaps. The interviews give the impression, that there are differences to low volume industries like the production of customer orders during pilot production or the lack of digital planning tools. However, this will not apply for all industries and company sizes and should be further researched with quantitative methods. Furthermore, this article provides interesting insights for the development of learning factories, which are also designed to for induced and autonomous learning [9]. If learning factories are to broaden the scope of their trainings, the organizational structure should be reevaluated based on the introduced criteria (training variety, frequency and level of changes between different products and production processes). Also, the operational structure and the activity for ramp-up robust learning island can be adapted for learning factories, as these also should be flexible and changeable for different trainings. Similar to learning islands, learning factories can also be used to focus on training an abstract concept or a concrete example with a varying degree of accuracy and a trade-off between a high model accuracy (higher potential for autonomous learning) and efforts must be made. Creating a flexible and changeable learning factory in the design phase should help to reduce the efforts.

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