Development Practices Supporting Resilient and Sustainable Production – Exploring Greenfield Projects

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Abstract

The green transition necessitates manufacturing companies to address climate change and incorporate sustainable and resilient solutions into their production. The best opportunity to achieve such solutions in production is during development, especially in greenfield projects with fewer constraints from existing production solutions. So far, the knowledge of how to achieve this is limited. Therefore, this paper aims to elaborate on how manufacturing companies can attain sustainable and resilient production. The focus is on development practices in greenfield projects and their relation to active ownership, collaboration and learning, potentially supporting the lasting impact of change initiatives. The paper builds on results from a multiple case study, including three greenfield production development projects. A research design, involving 22 semi-structured interviews and four workshops, was applied. An analytical framework was developed to support the analysis, including active ownership, collaboration and learning. In total, 21 different development practices were identified and categorised into active ownership, collaboration, and learning. The paper contributes a new perspective on production development. As an alternative to the traditional planning-and-control perspective, a learning perspective on production development was applied, which is increasingly required for production development processes addressing new domains, such as the green transition.

Keywords
resilient production, sustainable production, production system, production development, green transition, workplace innovation

Introduction

Climate change and environmental degradation pose existential threats not only to the European Union but also to the global community. Considering the significance, the European Commission has introduced a series of policy initiatives. The European growth strategy, known as the 'Green Deal,' serves as a roadmap with the ambitious goal of transforming Europe into a climate-neutral continent by 2050 (EC, 2019). The overall objective is to detach economic growth from environmental degradation. The associated Industrial strategy, which emphasises endeavors to establish modern, resource-efficient, and sustainable industries, as well as the transition to a circular economy, underscores the pivotal role of the manufacturing industry in meeting the objectives of the 'Green Deal' (EC, 2021). In addition, adopting a human-centric perspective, where technology serves people, in combination with resilience and sustainability, is advocated for the future manufacturing industry (Breque et al., 2021). The green transition, in combination with the high pace of change and increasing complexity, challenges the manufacturing industry, and conditions for resilient and sustainable production need to be created.

The emergence of concepts such as sustainable production is driven by the intention to accelerate positive change and contribute to a more favorable world for future generations (Garetti & Taisch, 2012). To support the green transition, the production system must be considered across its complete life cycle — from the initial planning and design phase to its eventual phase-out (Johansson et al., 2019; Scharmer et al., 2023). So far, there is a lack of guidance that indicates relevant actions to achieve sustainable and resilient production (Scharmer et al., 2023). Studies focusing on production have been overshadowed in handling the environmental issue (Sarkis & Zhu, 2018). Furthermore, the number of conceptual studies on sustainable production still dominates in numbers compared to empirical studies (Jasti et al., 2022). Among the existing studies, a majority deal with brownfield development, which is the situation when an existing production system is refined or reorganised (Bellgran & Säfsten, 2010). However, during the development of new facilities in greenfield projects, there is a unique opportunity to rethink previous solutions and take larger leaps (Nåfors, 2021).

To be able to live and act in resource-efficient and sustainable economies, development projects must foster lasting impact in organisations (Svensson & Brulin, 2014). Until now, research on how the development of resilient and sustainable production can be enabled and supported is limited. As indicated above, current development practices, here defined as the activities, methods, and tools employed to design, improve, and innovate production systems, need to be revisited and potentially refined. The purpose of this paper is to elaborate on how manufacturing companies can attain sustainable and resilient production. The focus is on development practices and their relation to active ownership, collaboration and learning, potentially supporting a lasting impact of change initiatives. To fulfil this purpose, two research questions were formulated:

1. What development practices may support the development of sustainable and resilient production?
2. How can active ownership, collaboration and learning enable and support relevant development practices during the production development process?

The paper builds on results from three empirical studies of development projects involving different types of production systems.

Production development and organisational change

Understanding development and change is complex and necessitates contextual understanding and an interdisciplinary approach (van de Ven & Poole, 1995). To address the research questions in this paper, theories related to production development and organisational change is presented below.

Production development

Production development involves creating effective production processes and development of production capability (Bellgran & Säfsten, 2010). Production development implies that needs are converted into relevant physical and organisational solutions (Cochran & Rauch, 2020). The most significant opportunity to achieve sustainable and resilient production is during the early phases of the production development process (Bellgran & Säfsten, 2010). In the same way as cost, most of the impact on sustainability and resilience is decided in the early phases of the development process (Ulrich et al., 2020). Production development is often considered to be part of the product realisation process, including both product and production development (Bellgran & Säfsten, 2010; Ulrich et al., 2020).

A production system is expected to support multiple generations of products; therefore, a long-term perspective is essential during the development process. However, in general there is a lack of long-term thinking regarding the development of production systems, even though the life cycle of the production system often surpasses that of a product (Boldt, 2023; Bruch & Bellgran, 2014). The product lifecycle and the lifecycle of the corresponding production system converge during the product's production phase, see Figure 1, and a challenge is the coordination between the product and the production system, which has become even more pressing in the strive for sustainability (EC, 2021; EFFRA, 2019).

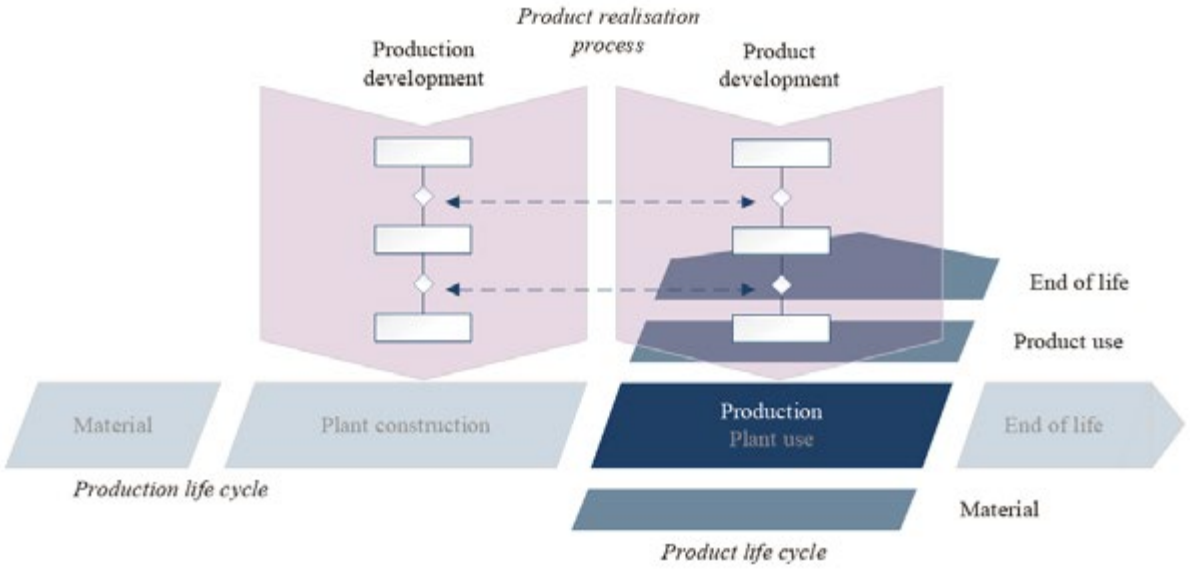

Figure 1. The intersection between product and production development (based on Vielhaber and Stoffels (2014) and Boldt (2023)).

Production development can involve the development of existing production plants (brownfield development) or establishing entirely new production facilities (greenfield development) (Nåfors, 2021). With a greenfield project, there is an opportunity to build right from scratch since the existing production system imposes fewer constraints (Bellgran & Säfsten, 2010). However, the development of production systems requires that many influencing factors are considered simultaneously. Furthermore, conditions may change over time due to the rapid pace of change, market demands, technology development, societal challenges, etc., impacting the sustainability dimensions but also requiring the capability of the manufacturing company to continually adapt and remain viable within uncertain environments, i.e., to be resilient.

Sustainable production

The urgency to act on climate change has encouraged manufacturing companies to take sustainability and circular principles into consideration when developing their production (Sarkis & Zhu, 2018; Skärin et al., 2022). Sustainable production strives to preserve resources while simultaneously promoting economic growth and improving human well-being. Definitions of sustainable production (Veleva & Ellenbecker, 2001) and sustainable manufacturing (Garetti & Taisch, 2012) commonly include the three dimensions of sustainability, social, environmental and economic, representing sustainable development (Purvis et al., 2019). Sustainable production implies that a life-cycle perspective is applied to a production system, from initial planning and design to the phase-out (Bruch & Bellgran, 2014; Stoffels & Vielhaber, 2016).

Resilient production

Resilience refers to the ability to recover quickly or easily from or resist being affected by disturbances of any kind (Oxford, 2023). It is a multidimensional concept with application across diverse fields (Essuman et al., 2020; Marchese et al., 2018; Negri et al., 2021). In the

context of Industry 5.0, resilience refers to increased robustness in industrial production, strength against disruptions, and the capability to provide and sustain critical infrastructure during crises (Breque et al., 2021).

The system should possess the ability to respond, learn, monitor and foresee potential critical events (Hollnagel, 2010), such as disturbances, problems, disruptions, and uncertainties – both planned and unplanned – that might influence the production system (Fjällström et al., 2009). Key to resilient production is the ability to adjust its functioning prior to, during, or following up on such events, where essential system abilities include knowing what to do, what to look for, what to expect, and finally the ability to learn from experience (Hollnagel, 2010). However, it is challenging to achieve resilience due to the complexity, which requires a system perspective on the production system to include aspects related to human, technology and organisation (Säfsten et al., 2023).

Production development from an organisational change perspective

A common way to approach production development is to suggest prescriptive production development models, often following a stage-gate logic (Bellgran & Säfsten, 2010). However, a challenge is the reluctance among manufacturing companies to use these development models to support production development (Boldt, 2023; Salim, 2021). The green transition necessitates manufacturing companies to adapt to sustainability challenges and incorporate relevant practices into their operations. Greenfield projects and the transition to sustainable and resilient production imply an organisational change. Therefore, an alternative approach may be to consider production development from an organisational change perspective.

Supporting organisational change initiatives

To succeed with such organisational changes, awareness of factors that can positively influence the outcome is essential (Errida & Lotfi, 2021). The area of organisational change is vast, and several models for organisational change exist (Galli, 2018). Beneath the different models, there are two underlying beliefs: a) change can be planned and managed through understanding a predefined set of steps, and b) change is an emergent, organic process that is not possible to manage in detail (Hallencreutz & Turner, 2011). The first belief (a) can be described as a structured approach, transferring individuals and organisations to a desired future state from a current state. The second belief (b) reflects an understanding of change as an ongoing learning process rather than a pre-defined series of steps (ibid). A distinction between planning-and-control models and process-and-learning models can be made (Elg et al., 2015). The former assumes that changes follow a set of predefined stages in a stable and predictable context, whereas the latter emphasizes on reflective practice and learning (Brulin & Svensson, 2012). The two approaches are not mutually exclusive; rather, both can be true at the same time.

According to Parry et al. (2013), organisational change, seen as a chaotic and complex process, can be managed continuously as it progresses. This involves interventions and

actions tailored to the project's current stage and state, providing ongoing adjustments to steer it towards a successful outcome. Da Ros et al. (2023) review highlights the necessity for change models to adapt to increasing complexity and uncertainties. Consequently, this demands a deeper understanding and consideration of organisational and human aspects in development and implementation processes.

It is essential that organisational change initiatives not just become temporary frenzy but instead lead to desirable effects in the organisations, lasting beyond a time-limited project (Svensson & Brulin, 2014). To succeed with this, three factors are relevant to consider: 1) active ownership, 2) collaboration, and 3) learning (Brulin & Svensson, 2012; Elg et al., 2015). These factors are interconnected and reflect a process-and-learning approach to change that is considered necessary in dynamic environments when previous knowledge or methods are limited (Brulin & Svensson, 2012). By addressing these factors during a development project, lasting and desirable effects can potentially be achieved, beyond the project (ibid).

The first factor, active ownership, ensures that the right conditions for the change process in terms of resources, governance, and attention, as well as means to take care of the results, are in place (Brulin & Svensson, 2012). Previous studies stress the involvement of top management, as changes are connected to organisational strategies, visions and goals (By, 2005). Leadership support involves enhancing skills and encouraging engagement and accountability for performance among actors in a change process (Bamford-Wade & Moss, 2010). As change initiatives strongly affect working conditions, a holistic understanding is needed that considers different actor's needs and interests (Docherty et al., 2008). Thus, change initiatives needs to be understood from the perspectives of working conditions providing both new opportunities, but also new prerequisites (Abrahamsson, 2022; Dhondt et al., 2023). Communication and transparency during change processes are regarded as important to enhance the understanding of different interests and set light on potentially contradictory demands (Svensson & Brulin, 2014).

The second factor, collaboration, is crucial for joint knowledge creation. Manufacturing companies need a variety of new capabilities to reduce their sustainability impacts, ranging from a more profound knowledge of materials usage to a rich understanding of social behaviour (De los Rios & Charnley, 2017). These capabilities rest upon cross-disciplinary competencies and collaboration. For example, intra-organisational collaboration involves cooperation between different organisational functions, and inter-organisational collaboration involves cooperation between different organisations. Collaboration in different forms is also crucial for achieving common goals (Boonstra, 2023). As the pace of change and development increases, it is regarded as increasingly important to achieve innovative collaborations among stakeholders that enhance flexibility and efficiency and consider aspects concerning socially sustainable work (Hasle, 2014).

The third factor, learning, is essential for workplace innovation, change, and new ways of thinking and acting. There are limitations in traditional linear approaches to change

implementation due to new development areas and the lack of possibilities to rely on previous knowledge or known methods (Elg et al., 2015). In work situations requiring rethinking and developing new approaches, a form of developmental learning occurs when individuals or groups experiment or test alternative ways of acting (Ellström, 2010). Such forms of learning are essential for organisations to increase their capability to handle or capture new or unexpected situations, problems, or challenges (Ellström, 2001). Aspects such as leadership, trustful relationships, communication and accessibility to relevant documentation impact on how an individual's learning can be transformed into organisational learning (Lundqvist, 2023; Wallo et al., 2013).

Analytical framework

To overcome the limitations of prescriptive stage-gate models, focusing on development practices may be a viable approach to support the creation of resilient and sustainable production systems. Development practices embrace the entire production development process, from planning to implementation and continuous improvement, with the aim of supporting efficiency, quality, sustainability, resilience and other requirements in the resulting production system. To achieve effects beyond a development project, the development practices may be connected to active ownership, collaboration and learning (Svensson & Brulin, 2014). With this as a starting point, an analytical framework for the purpose of this paper was developed, see Figure 2.

Figure 2. An analytical framework to support elaboration on development practices and their relation to active ownership, collaboration and learning (inspired by Svensson & Brulin, 2014 and Harlin, 2024).

Method and material

The results presented in this paper have been developed within an interactive research project focusing on the development of resilient and sustainable production (Säfsten et al., 2023). Interactive research implies that practitioners and researchers collaborate during all phases, from initiation to closure of a research project (Ellström et al., 2020; Svensson et al., 2015). For this paper, empirical data from three case studies have been included. The unit of analysis was development projects (Yin, 2018) carried out in three different organisations, see Table 1. The objective and the length/time frame of the studied development projects varied, as further described below. From here on, the studied development projects and involved companies are denoted as *Joint building* (Company Assistance), *Future bread production* (Company Generation), and *School kitchen* (Company Project Management); see Table 1. All three projects were classified as greenfield development, i.e., new facilities were planned. All companies had existing production facilities, which, to varied degrees, affected the new production system. Case Joint building and case Future bread production represent the industrial/private sector, and Case School kitchen the municipality/public sector. The development projects represented the development of different production systems.

Company alias	Description	Studied development project (project time)
Assistance	A manufacturing company with approximately 220 employees (year 2023), part of a large investment group. One production plant in Sweden	Joint building (2017-2024)
Generations	A family-owned food production company with approximately 260 employees (year 2023). Two geographically separated production plants in Sweden.	Future bread production (2020-ongoing)
Project Management	An industrial consultant company with four employees (year 2023), part of a group. Supporting organisations in different sectors with construction project management.	School kitchen (2021-2023)

Table 1. Industrial settings and studied production development projects

Data was collected through interviews and result workshops, see Table 2 for an overview. The interviews were semi-structured, and an interview guide was developed and anchored by the contact person at each company. The interview guide included questions about the respondents' background, roles, and experiences, as well as their understanding of sustainability and resilience in the context of production development. It also included in-depth questions about how the company worked on production development in general, and questions about the studied development project. Furthermore, questions capturing successful and hindering practices for the development of sustainable production systems were included. As was question about critical events and measures to manage these, in order to capture aspects related to resilience.

In each case, key persons were selected as respondents. In the case Joint building and Future bread production, the respondents were project managers, sub-project managers, production engineers, production managers, sustainability directors, and representatives from human resources, communication and IT departments. In the case of the School kitchen, several respondents were associated with the customer (a municipality) and the construction entrepreneurs. Therefore, the respondents included different functions and responsibilities, i.e., a school principal, a facility strategist, design manager, architect, and an installation specialist (electricity and security). The interviews were recorded and transcribed verbatim.

Workshops are an important element in interactive research (Berglund et al., 2020; Ellström et al., 2020). During the result workshops, the attendants were primarily the respondents in each company. However, both in case Future bread production and School kitchen additional persons participated. Notes were taken during the workshops. During the workshops, experiences were shared, and new insights were gained among the participants. The result workshops created an arena for discussion between academia and industry concerning a specific topic and, thereby, also an arena for learning. All interviews and workshops were carried out via the digital platform Teams.

Case study	Interviews	Result workshop
Joint building	Seven initial interviews, between 35 and 60 minutes.	On two occasions, there were a total of seven unique attendants (all respondents).
Future bread production	Eight initial interviews, between 32 and 80 minutes (Feb-May 2023). Four follow-up interviews, between 28 and 55 minutes (May 2024).	On two occasions (Dec 2022, Feb 2023), in total eight unique attendants (seven of the respondents and one additional person).
School kitchen	Seven interviews, between 31 and 90 minutes (January-June 2022). One interview involved two respondents.	On one occasion (Feb 2023), in total seven attendants (five of the respondents and two additional persons).

Table 2. Case study details

On an overall level, the analysis of the qualitative data followed the structured process suggested by Miles et al. (2019), involving data condensation, data display, and drawing and verifying conclusions. The analysis started with within-case analysis, and the results were presented and discussed at each company.

For this paper, the data was revisited, and a two-step analysis was conducted. The first step involved identifying development practices in each case. This process was guided by the questions posed regarding successful and hindering practices for the development of sustainable and resilient production systems. Quotes were used to illustrate how the development practices appeared in the data for each case. To ensure the confidentiality of

the participants involved, all quotes are provided without specific references to the roles of the respondents. During the second step of the analysis, the theoretically derived analytical framework was used, and thereby, it was possible to interpret the empirical results through a theoretical lens. Two researchers independently carried out the analysis, i.e., researcher triangulation, which strengthens the validity of the results (Yin, 2018).

Results

In this section, each case is described in detail. Initially, the context and the studied production development project are introduced. The described development practises are presented, followed by the measures taken to manage potential critical events.

Case Joint building

Company Assistance was co-locating activities from four different facilities into one new joint building. In addition, activity-based workplaces were planned for in the new facility. The purpose was to become an attractive employer and showcase a modern facility. A strong focus was on aspects related to social sustainability. One goal of the project and of the co-location was to create "one Company Assistance". Through the co-location of R&D, production, sales, and all other functions in the company, an innovation hub was envisioned, which was expected to secure the company's economic survival. Another goal was to create a best practice example of an accessible workplace. Accessibility and inclusion were described as part of the company´s DNA: "...in terms of accessibility, we really believe in this, being inclusive is part of the whole company DNA." Both economic and environmental sustainability were also important, although thinking economically was described as natural. The environmental requirements of the new building were ambitious, adapting to the LEED (Leadership in Energy and Environmental Design) gold certification.

To manage the co-location, two closely connected development projects were formed: a real estate project focusing on planning and building the facility, and a relocation and change project focusing on planning and implementing the co-location. In this study, the focus was on the relocation and change project. An informal project start was described in 2017, and the planned end date was September 2024. A formal project manager was assigned in 2021. A part-time consultant was assigned to support the project team with the real estate part of the project. An overall steering group was assigned, and a local steering group was formed to support the project manager. For each of the areas to be relocated, e.g., R&D and production, sub-project managers were assigned.

Good preparatory work was described as key to succeeding with the project – to understand what to do and how to do it, and to prepare people for change. During the project, a strong focus was on change management to get everyone on board. Another perceived success factor was the support from well-resourced owners with a strong commitment to

sustainability, who stood behind both Company Assistance and the construction company responsible for the building.

Development practices

Management involvement was perceived as essential for raising awareness of sustainability issues within the organisation. Through the involvement of key persons in the project team, it was perceived that the possibility of finding and using sustainable solutions increased: "... the key people who have been a little higher up, and then linked to the steering group and such, who are also very driven in bringing out sustainability issues and finding solutions and not making compromises."

The cross-functional integration was mentioned as important for the possibility of finding sustainable solutions. Not having a holistic view, integrating relevant perspectives and functions could have long-lasting consequences "... it's like the old saying – as an engineering designer, you can design in more problems than a production technician can eliminate in a lifetime, just in one morning."

During the development phase of the project, the operationalisation of goals was mentioned as challenging. In the case of Joint building, with a strong focus on social sustainability, operationalisation of their accessibility goal was perceived as challenging. However, it also gave an opportunity for the involved partners to learn. As one example, some of the accessibility adaptations were perceived as challenging by the construction company, but at the same time, it gave them a learning opportunity: "At the same time, they may also be tempted to learn more, because this may be in their interest to also gain knowledge about". The operationalisation of goals also gave rise to a conflict of interest. Some of the suggested solutions that were better from a sustainability perspective were not possible to realise due to the time frame of the project or due to economic reasons.

In the assembly plant, the emphasis was on layout planning and material flows: "We have worked a lot with layouts and flows and how that part should look". The ambition was to involve operators, and other employees close to production, aligned with their ordinary way of working in production development: "... they [production personnel] are not just here to screw or move things in the warehouse; they must also improve the processes they work in." When different automated production solutions were discussed, the importance of not limiting future development was mentioned. They were currently reluctant towards automation solutions, with the main argument: "... automated solutions may not be quite there yet, and we may not really want to buy into such a solution right now."

Measures for handling potential critical events

In the case of the Joint building several measures aimed at handling consequences from disturbances or potential threats were described. They had assigned a group to foresee potential critical events proactively. Experience from previous relocation projects in the company was part of the input. In production, the competent and flexible staff was described

as able to handle all possible variants. To avoid unnecessary challenges during the relocation project, a planned change of the business system was postponed until after the move to the new facilities. The entire project was driven by the vision to become an attractive employer for the future. They described a high ability to solve problems, especially in stressful situations: "... we are quite good at firefighting, to solve the problem." Although several preventive measures were employed, they described that their weak spot was to prevent critical events from appearing in the first place.

Case Future bread production

Company Generation was setting up a new production plant focusing on resource-efficient production, flexibility, scalability and sustainability for future competitiveness. By 2032, the goal was 100% circular production and fully automated production. The company's sustainability work was largely driven by the owners' high ambitions, where the focus was on circularity with minimal footprint.

The development project was initiated because of a fire where a newly built, but not yet inaugurated, production line burnt to the ground together with the rest of the facility. The development project's time frame was largely governed by the terms and conditions related to the insurance. The project start was in August 2020. While the project was ongoing, several external factors, such as raw material availability and customer behaviour, required adjustments to the project content. However, they perceived that their ability to adapt to surrounding changes was good: "... the world is so changeable, and the company is like an amoeba, changing all the time." In 2024, the project activities were partly transferred into daily work, and smaller and specific development initiatives were ongoing related to the overall goals initially formulated.

The project was divided into different stages, the first of which was to rebuild the burned-down plant. The second stage included forward-looking work to identify future product needs and optimise current production facilities, and the development project started at the beginning of 2022. Activities were divided into five subprojects, including (1) future offering, (2) building and construction, (3) process and machine, (4) IT/OT (Information and Operational Technology), and (5) organisation and future competence. The work was described as genuinely cross-disciplinary. The company had a holistic view of sustainability, including economic, environmental, and social aspects, which was reflected in the project team. A project model was applied to guide the work, including project directives, a steering group and clear project goals.

The focus of the study was on the second stage of the project. The overall goal, 100% circular production and fully automated production by 2032, aligned with the company's overall sustainability goal. Sustainability was described as part of the DNA of the company and thereby naturally included in all their activities. To succeed, sustainability was considered important to be part of the daily work, not something added on. The determination of the

owner family was described as an important prerequisite for successful progress in the project. Another success factor was the well-anchored goals, and the plan jointly formulated, together with performance indicators following up the progress. An innovative climate, being open to different scenarios, was emphasised as important for the development process.

Development practices

The value of a transparent process was emphasised in the case of Future bread production. It was perceived as essential that everyone understood the process and the decisions made. In addition, when designing a new system solution, the need for communication and synchronisation between subprojects was emphasised. To secure internal communication, both between sub-projects, but also in general, was key.

At Company Generation, sustainability was part of the daily work. However, a challenge to operationalise sustainability goals was brought forward, illustrated with this quote: "We should be 100% circular, yes okay, but what does that mean?". Related to the operationalisation of goals, there were some conflicts of interest. Some of the solutions that were better from a sustainability perspective were not possible to realise due to the time frame of the project or due to economic reasons.

During the development of production solutions, new ways of working were required. Due to organisational changes in Company Generation, relevant in-house competence was no longer available and therefore, collaboration with external engineering designers was required to design the required production solutions. In addition, challenging aspects related to manufacturing equipment were mentioned. They perceived that not all manufacturing equipment suppliers could deliver equipment that fulfilled their sustainability requirements, such as machines for packaging that functioned reliably with the modern plastic bags used by the company. Another challenge mentioned was to evaluate to what degree different system solutions contributed to the sustainability goals, and a need for some kind of decision support was requested.

Measures for handling potential critical events

The starting point for the case Future bread production was a major critical event, a fire. A new production line burnt to the ground with the rest of the facility and 75% of their production capacity was lost. This experience contributed to some production solutions developed in the studied development project. One key aspect during the project was to achieve redundancy – to reduce the dependency on specific equipment, production lines or individuals: "…we try to become less *individual-dependent* as well, but knowledge should be spread and preferably available as close to the operations as possible". The goal was that it should be possible to produce the top nine products at both their production facilities. This was also expected to contribute to the flexibility required to manage unpredictable customer behaviour and large demand variations. Another key aspect was security, striving for high-security awareness. As described by the respondents, they have built a capacity to manage crises. Despite the devastating event (the fire), their attitude was optimistic. For instance, they

tried to turn adversity into advantages. As one example, the fire gave media attention, which was perceived as valuable for the company.

Case School kitchen

Company Project Management was an industrial consultancy company that supported organisations across different sectors with construction project management. Their mission was to contribute to a sustainable society through systematic project improvement. The business idea was to systematically lead, design, and further develop sustainable projects, using expertise from all project phases.

The development project, i.e. the case School kitchen in a primary school, involved a major investment in a new school kitchen, fulfilling the sustainability goals of the municipality. The objectives were to increase the production capacity of daily meals (portions) and to create a suitable and improved dining environment for the pupils. The school kitchen dining environment was considered specifically important for pupils' well-being, performance and learning ability in their schoolwork.

The assignment was to transform the function of the existing kitchen from a 'receiving' kitchen to a full production kitchen to enhance meal production capabilities, addressing individuals' and customers' preferences and improving service quality. The new kitchen was to have the capacity to produce 750 portions daily on-site and additionally deliver 150 portions for external distribution, for example, to customers within elderly care in the municipality. Moreover, future utilisation of the school kitchen was discussed, including possibilities for use for public education activities. Thus, it was important to have an innovative climate in the development project, being open to different scenarios for the future production system, i.e. the new school kitchen.

A diverse project team was assigned to the development project and comprised engaged participants from different organisations. A project leader coordinated the entire development project and acted as a link to multiple stakeholders, for example, the municipal decision-makers, school administration, specialists, and community stakeholders (e.g. pupils). The project team collaborated closely with representatives from the municipality and controllers within different disciplines and included functions such as architects, engineers, production management specialists, and construction contractors.

The development project started in 2021 and was completed in August 2023. The starting point of the development project was a feasibility study conducted by the municipality. The feasibility study was the foundation for the municipal decision to develop the school kitchen. It involved evaluating the project's scope, financial implications, technical requirements, and potential impacts on the school's daily operations and community.

Development practices

During the planning of the development process, a common mindset and broad understanding among different stakeholders were mentioned as aspects affecting the possibility of achieving sustainable production in the forthcoming school kitchen. Specifically concerning environmental considerations and how to incorporate sustainability into the planning phase to ensure that the project aligned with broader environmental goals and long-term perspectives: "It is important to find long-term and functional solutions... but the long-term aspect can also be a bit problematic because there is so much, we don't know about future effects." To achieve this, early involvement and collaboration were described as key. In the case of the School kitchen, the importance of leadership guiding all involved parties with different interests and requirements towards a common goal (addressing sustainability aspects) was emphasised as important. It included joint analysis: "Having a serious discussion about what might happen."

The importance of the planning phase should not be underestimated, which became clear from the case School kitchen. Limitations in the pre-study, such as resource availability, conflicting requirements, and a lack of documentation, caused challenges later in the process. Case School kitchen, associated with the construction sector, described an immaturity in their industrial sector concerning standards for production development in general, and for sustainability aspects in specific, which affected the project. As described by the respondents, a standard work procedure and tools developed for the sector would be helpful.

It was perceived as important to choose solutions that were not limited to future needs and development beyond the actual requirements of the new school kitchen. To be able to develop sustainable production solutions, Company Project management perceived it as essential to inform and educate involved parties about relevant sustainability aspects: "It is important to understand why it is important, and how to optimise solutions for specific situations."

According to the respondents, the construction sector's interest in circular production solutions was still limited. In practice, the realisation of "re-use" solutions was perceived as challenging due to a lack of systematic ways of working with circular solutions. A specific challenge addressed was the design and implementation of temporary solutions ensuring safe and functional workplaces and a temporary school kitchen while advancing the new school kitchen: "...one might focus very much on what is to come, but how do we maintain sustainability during the period when the work is moving forward?". For example, ensuring continuity and safety of operations, efforts to reduce negative environmental impact that may arise from construction activities, and education and communication, including all parties that may be affected by the change.

Measures for handling potential critical events

The respondents expressed examples of several potential critical events that required consideration in the development project of the new School kitchen. One example was how

equipment problems in the kitchen would have impact of the kitchen operations and require alternative ways of working. It may lead to switching to paper plates when dishwashing machines break down. Such changes can temporarily alter the workflow and require a workplace design allowing adaptation. Another example of potential critical events was related to shortages in raw materials and transportation issues, necessitating adjustments in the workplace design to ensure possibilities to manage the logistics. Additionally, a critical event concerned the kitchen staff that applied work rotation between different school kitchens. Thus, the development project needed to consider how to ensure a flexible but standardised workplace. Another aspect was how the kitchen could be flexible and adapt to fluctuations in the number of produced meals and prerequisites for scaling up and down. Moreover, how to create possibilities to utilise the school kitchen for customers other than pupils, e.g., for education or public events.

Development practices supporting resilient and sustainable production

In this section, the development practices derived from the three cases are compiled.

Development practices

Development practices were defined as the activities, methods, and tools employed to design, improve, and innovate production systems. As a first step of the analysis, development practices applied to support the development of sustainable and resilient production were derived. The result of the analysis is presented in Table 3. Each development practice is supported by one or several illustrative quotes from the case studies, marked with a note indicating which case (1 represents case Joint building, 2 represents case Future bread production, and 3 represents case School kitchen).

Table 3. Empirically derived development practices from the three case studies

No.	Development practices	Illustrative quotes
#1	Leadership committed to sustainability	"... the key people who have been a little higher up, and then linked to the steering group and such, who are also very driven in bringing out sustainability issues and finding solutions and not making compromises." [1] "... the success factor for success is, of course, that this is a high priority point for management." [2]
#2	Engaging parties with strong commitment	"There is a huge commitment from all different parts... it's a privilege to be a part of this journey." [1] "We have ambitions that go beyond legal requirements." [3]
#3	Integrating sustainability as part of the daily work	"Sustainability as part of the ever-present, ever-present, no side project." [2]

No.	Development practices	Illustrative quotes
		"This understanding [concerning sustainability] is good to avoid being misled... so you can ask questions... at least have a discussion about it."[3]
#4	Clear sustainability goals	"The LEED Gold certification requires quite a lot more than if we were not to go down that track ..." [1] "... environmentally, it is these LEED standard requirements that will guide us in that we have high environmental goals." [1] "We have very strong sustainability goals that we share together with the property owner... not just environmental goals in the form of CO2-neutral property or energy-smart solutions, ... also, on mental and physical health... and world-class accessibility." [1] "It is important that goals are set, so that we have something to work on and that we are measured by that." [2] "... to keep it together, that we still have a common goal and a common plan going forward, which is the overall one for the company, which is well anchored, I think is a success factor." [2]
#5	Relevant competence	"... competence I can think too, this to know what you are looking for, knowing what parts to look at ..." [2]
#6	Considerations of market demands	"... the project team is as formed to cover as much of the business as possible to, from the impact of our consumers, to as well as delivery, completion of products and also beyond." [2]
#7	Create good work conditions	"... sustainable working methods, develop over time and not depend on one person." [1] "The important thing is to make it work well for people. It's not easy. No matter how experienced you are, it's always important to be careful and pay attention to details." [3]
#8	Transparent work process	"... to sort of create a process, to clarify it, that you understand both the process and the decisions." [2]
#9	Use of standards	Standard components: "Use products from the approved product database ..." [3] Standard equipment: "...we build lines so that you can run products on more than one line, to achieve redundancy if something happens..." [1] Standard work procedures: "... Then there is also the issue of the needs and perspectives of different people and stakeholders. That you may have a lack of demand and systems schedule for reuse and circular construction. We also talk very little bit about the immature construction industry that there is no particular industry standard." [3]
#10	Building trustful relationships	"Building relationships... you create trust and cooperation between each other... and educating each other" [3]
#11	Collaboration with system suppliers	"...maybe it's something that we also need to pursue together with one or more suppliers to get where we want to go in the long term." [2]

No.	Development practices	Illustrative quotes
		"Transition to external actors required new ways of working: … No in-house designers who can draw on these solutions, technical improvements and things like that …" [2]
#12	Collaboration between functions	"And it's like the old saying – as a designer, you can design in more problems than a production technician can eliminate in a lifetime, just in one morning." [1] "Local steering group: …represents all functions, plus finance, controlling and purchases because there are a lot of procurements we have to do. And then there's… project manager for the various relocation projects." [1] "Sustainability as part of the daily work, ever-present, no side project." [2] "… that we have worked together, the products of the future, it is not some sales organisation that has come up with something we are going to manufacture, but we have kind of worked together." [2] "… collaboration across departments in some way, to work less in these silos we have, but really embrace each other's knowledge even more." [2]
#13	Secure good conditions during development	"You might focus a lot on what is to come, but how do you maintain sustainability [in the temporary solution of the school kitchen] while working forward?" [3]
#14	Long-term perspective in selected solutions	"To build long-term sustainability for those who will manage the property and the operations …" [3] "It is important to find long-term and functional solutions… but it is precisely the long-term aspect that can be a bit problematic as well, because you do not know much about the effects that can come in the long run." [3] "We want to design the kitchen for flexibility and adaptability [in case of any disruptions or changes]." [3]
#15	Create preconditions for circular production solutions	"… but we have no way of storing old sinks and reinstalling them in 1.5 years. It does not work without a system." [3] "I become enthusiastic when we found solutions for reuse in the temporary dining hall, discovered that you can make money from reuse." [3]
#16	Provide opportunities for joint problem-solving	"We believe that collaboration between organisational boundaries is a foundation for creating creative ideas – that is, innovations […], you need to have your ear to the ground, you need to have the pulse of the market, you need to work smart in all kinds of support functions to get this culture of innovation." [1] "I can imagine that they are challenged about some of our social parts around the accessibility adaptations and such. At the same time, they may also be tempted to learn more …" [1]

No.	Development practices	Illustrative quotes
		"It is important to understand why it is important and how you can optimise solutions for specific situations." [3] "... and the idea is to be able to take experiences with you at all levels, in the project group and also us as contractors." [3]
#17	Updated and accessible documentation	"We have succeeded in this [development project], and we feel secure with the construction documents we have produced today, and it is approved by all different stakeholders." [3]
#18	Plan for the unplanned	"Unknown uncertainties always arise – leave some leeway in the timetable." [3] "There is a risk of boxing yourself in, considering possible changes in the future." [3]
#19	Creating an ability to handle critical events	"…. I actually think the company has a pretty good ability to handle both this and that" [1]
#20	Learning from other sectors	"Bringing the expertise from the construction side into the industry is quite interesting... I think there is a great exchange in both directions." [3] "They [public sectors] have tried to copy tools from industry to develop a production system for construction production... it has not permeated organisations; they have not managed to adapt tools suitable for our sector" [3]
#21	Operationalisation of goals	"We should be 100% circular, yes okay, but what does that mean?" [2]

[1]Case Joint building; [2]Case Future bread production; [3]Case School kitchen

Enabling and supporting development practices

The result from the second step of the analysis, to understand how active ownership, collaboration, and learning can enable and support the development practices during the development process in greenfield projects, is presented in Table 4. The derived development practices were categorised according to the aspects associated with the three factors of the analytical framework

Table 4. The relation between development practices and aspects of active ownership, collaboration and learning

Factor	Aspect	Development practices *)
Active ownership	Vision and goals	#1, #2, #3, #4, #6, #14, #21
	Leadership	#1, #3, #4, #6, #13, #18
	Trust, empowerment, good working conditions	#2, #5, #7, #10, #15
	Resources (e.g. technological, organisational)	#5, #9, #15
	Transparency and communication	#8, #17
Collaboration	Intra-organisational collaboration	#12, #16
	Inter-organisational collaboration	#11, #16, #20
Learning	Work situations fostering learning	#10, #16, #20
	Relevant and accessible documentation	#17
	Ability to capture the unexpected	#13, #14, #18, #19

*) Identified development practices in the three case studies, see Table 3:

#1. Leadership committed to sustainability
#2. Engaging parties with strong commitment
#3. Integrating sustainability as part of the daily work
#4. Clear sustainability goals
#5. Relevant competence
#6. Considerations of market demands
#7. Create good work conditions
#8. Transparent work process
#9. Use of standards
#10. Building trustful relationships
#11. Collaboration with system suppliers
#12. Collaboration between functions
#13. Secure good conditions during development
#14. Long-term perspective in selected solutions
#15. Create preconditions for circular production solutions
#16. Provide opportunities for joint problem-solving
#17. Updated and accessible documentation
#18. Plan for the unplanned
#19. Creating an ability to handle critical events
#20. Learning from other sectors
#21. Operationalisation of goals

Discussion and conclusion

To support the development of resilient and sustainable production a multitude of aspects need to be considered. In this paper, three case studies lay the foundation for analysing development practices and their relation to active ownership, collaboration and learning. These factors are considered relevant, specifically in a dynamic environment, as they influence development and change initiatives and their outcomes in a long-term perspective (Brulin & Svensson, 2012; Elg et al., 2015), which is key in production development.

Sustainable and resilient production

The purpose of the paper was to elaborate on how manufacturing companies can attain sustainable and resilient production. Previous research has pointed out that circularity and sustainability discussions are often limited to a company's sustainability department (Ritzén & Sandström, 2017). However, the studied development projects indicate that sustainability has become a natural area to consider in manufacturing companies and integration of sustainability as part of the daily work was one of the derived development practices, see Table 3. From what we have seen in our studies, the two manufacturing companies have integrated sustainability as a natural area to consider, as previously done with other megatrends such as IT and quality (Lubin & Esty, 2010). The study in the municipality (School kitchen) demonstrated how aspects related to sustainability and resilience in practice were integrated into a greenfield project. Despite that, it was perceived that the industrial sector had more experience addressing these issues than municipalities. However, to succeed with organisational change, copy-paste is not advocated since comprehensive contextual understanding is essential (van de Ven & Poole, 1995). Thus, the ability to interpret and adapt overarching sustainability requirements to the own local organisation's context will be required.

The studied development projects focused on sustainability and circularity rather than on resilience. However, during the study's time frame, major external critical events challenged the manufacturing industry and other organisations. For example, the Covid-19 pandemic, lasting between January 2020 and March 2023, interrupted ordinary practice and called for new ways of working in the manufacturing industry (Ardolino et al., 2022; Kapoor et al., 2021). Another major event affecting the manufacturing industry was the Russian large-scale invasion of Ukraine in February 2022. This, together with some of the company's own experiences, such as a fire, has increased the awareness of the need for resilience in production. In the studied development projects, several actions were carried out to handle critical events, but also to prevent possible future critical events, aligned with the resilience strategies suggested by Hollnagel (2010).

Some of the solutions contributed to both sustainability and resilience. One example was the effort in case Future bread production to create redundancy in production, both among equipment and people. Redundancy enhances resilience by making systems more reliable, flexible, and capable of handling disruptions (Kamalahmadi et al., 2021). When managed properly, it can also contribute positively to sustainability by reducing waste, improving resource efficiency, enabling sustainable sourcing and more efficient lifecycle management of equipment. The relationship between resilience and sustainability has been extensively discussed in areas such as industrial ecology and environmental management (Fiksel, 2006; Marchese et al., 2018). Three main approaches can be found in the literature: 1. resilience as part of sustainability, 2. sustainability as part of resilience, and 3. resilience and sustainability as separate objectives lacking hierarchical structure (Marchese et al., 2018). In the manufacturing industry, close to production, the latter perspective seems dominant.

However, this study indicates that considerations of resilience and sustainability may be intertwined and need to be integrated in early design phases.

Enabling and supporting development practices

To enhance understanding of how to develop resilient and sustainable production systems, the approach was to identify and explore development practices, i.e., activities, methods, and tools, employed to design, improve, and innovate planned production systems. Depending on how these practices are managed, they may either support or hinder the development of production systems. As a result of the analysis, a total of 21 development practices were derived and categorised into active ownership, collaboration, and learning, according to the selected analytical framework. Development practices related to active ownership dominated, where aspects associated with vision and goal, leadership, trust, empowerment, and good working conditions were most common.

Some of the derived development practices were of a general character, not explicitly related to sustainability or resilience. Among these were, for example, the importance of management involvement, joint problem-solving, updated and relevant documentation, ability to identify and respond to critical events, transparent processes, and competence. Several of these more general practices, considered important for succeeding in development projects, have also been recognised as important in other development contexts (Svensson & Brulin, 2014).

There were also several development practices explicitly related to sustainability and resilience. First and foremost, a strategic priority and leadership commitment to sustainability was mentioned as key to success. This has also been pointed out in other studies. The implementation of the sustainable and circular manufacturing concept faces technical, organisational, and managerial challenges (Alayón et al., 2022; Sopjani et al., 2020). Involvement of top management is required, as is inclusion in the company's vision and strategy (Rashid et al., 2020; Schöggl et al., 2024). One potential way to create a common understanding and shared vision related to the implementation of sustainability is through common goals and joint performance indicators (Arekrans et al., 2023). Highlighted as important related to the implementation of sustainability goals is the hierarchical alignment between company vision and goals and the engineering practice (Arekrans et al., 2023).

Several development practices were related to collaboration, both intra- and inter-organisational collaboration. Previous studies have also emphasised that a lack of integration between different functions within the organisation and poor collaboration hinder the transition towards circular and sustainable solutions (Ritzén & Sandström, 2017; Sopjani et al., 2020). All three case studies addressed the importance of joint problem-solving, discussing potential solutions and their consequences for different actors. Collaboration during the development projects involved discussions about temporary solutions, ongoing operations, and the forthcoming future production system. Many times, it was perceived as

essential to collaborate with external systems and technology suppliers to learn and develop relevant solutions, something previously pointed out as key for small and medium-sized companies (Alayón et al., 2022). Numerous authors have investigated the integration of various organisational functions and emphasized its importance for sustainability (Ulrich et al., 2020). Previous studies offer valuable insights into the crucial role of collaboration in achieving sustainability goals and improving overall organisational performance (Jasti et al., 2022).

New problems occurred over time, and there was limited possibility of relying on previous experiences in the three studied development projects. The results showed that competence development was achieved by collaboration across traditional borders during the different development phases. Enhancing competence related to sustainability and resilience among functions and different actors was regarded as a cornerstone for achieving desired outcomes. Through high attention and awareness among the participants in the development projects, issues could be addressed in new ways. The development projects served as an arena for the co-creation of knowledge, enhancing competence development for actors, and beneficial both within and beyond the actual development project.

As noted by Brulin and Svensson (2012), a key challenge is maintaining development practices over time. They emphasise the importance of balancing active ownership, broad stakeholder collaboration and opportunities for continuous learning as key enablers for not only reaching short-term goals but also creating conditions for maintaining long-term effects. This aligns with the findings in this paper, particularly regarding the need for structured collaboration in the early planning and design phases. Operationalising these aspects in production development projects required active efforts among different functions within the production development team. For example, teams worked to develop innovative solutions and establish iterative feedback loops, which fostered continuous learning and supported the adaptability needed for sustainable outcomes.

The analytical framework applied in this paper originates from a model initially developed by Brulin and Svensson (2012) based on experiences from evaluations of large-scale research programmes (Brulin et al., 2012). The framework's broader applicability, as demonstrated in this paper, is supported by its use across diverse change and development contexts. For instance, the framework has been employed to study the conditions that foster sustained implementation of lean practices in the public sector (Lindskog, 2016). Additionally, it has been utilised to analyse industrial startups in organisations from both public and private sectors, rapidly implementing required work practices as an immediate response to the COVID-19 pandemic crisis (Harlin, 2024).

Throughout the case studies presented in this paper, development was characterised by uncertainties, a high degree of novelty, and interdependencies between actors to develop solutions. The analysis revealed that active ownership, collaboration, and learning were

essential during production development projects, supporting the planning, design, and implementation of solutions in greenfield projects.

Managing greenfield development and ongoing production

As a serendipity result of the three case studies, an expansion of the general production development process was suggested. Major changes in parallel with daily production required temporary solutions both in the case of the School kitchen and in the case of Future bread production. In the case Joint building focus was instead on minimising the downtime in production during the relocation, which required highly detailed and careful planning of each step. To emphasise the need to consider daily production, the activity of Designing temporary solutions was added to the generic development process, see Figure 3.

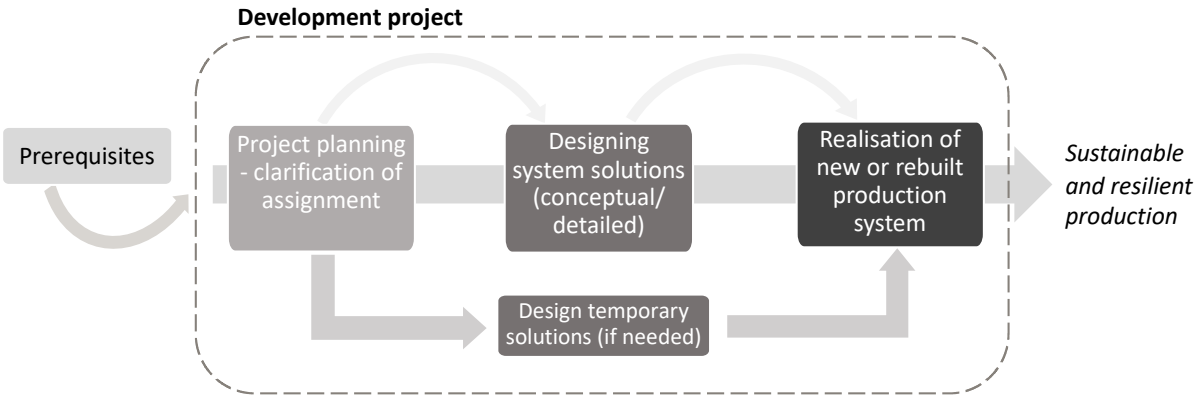

Figure 3. The production development process applied in the case School kitchen and in the case Future bread production.

According to the literature, greenfield development projects imply that current production systems have fewer constraints for realising potential solutions in comparison with more established production systems (Harlin & Berglund, 2021). However, our studies showed a continuous need during ongoing development projects to relate to their context/client and understand the constraints, especially since the development projects were carried out in parallel with already ongoing activities/production.

The case studies highlighted that greenfield projects were characterised by uncertainties and a lack of knowledge about how to develop solutions. Despite the high attention to sustainability, there was a notable lack of expertise in formulating the assignment and operationalising sustainability goals. Thus, contextual understanding and supportive leadership in the development projects were needed.

Theoretical and practical implications

The paper contributes a new perspective on production development, addressing the necessity of a learning perspective as an alternative to the traditional planning-and-control perspective. This perspective, illustrated with development practices derived from three cases and categorised as related to active ownership, collaboration and learning, is considered increasingly required for production development processes addressing new domains, such as the green transition.

Developing resilient and sustainable production is a complex task that demands a deep understanding of the prerequisites for sustainability and resilience, along with a comprehensive system perspective. A clear and well-anchored strategic goal among functions and organisations is required, as active ownership is a means to operationalise the goals. In addition, greenfield projects, in parallel with daily operations, require maintained operations during an ongoing development project, with a focus on the final goal of the development project and scenarios for the production system beyond the actual development project.

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