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The nature of underground innovation: Missionary, user, and exploratory orientation

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ABSTRACT

Bootlegging and creative deviance studies have described "underground" innovations, which employees develop without managerial consent but with company benefits in mind. This phenomenon is explained by structural strain theory: when organizations have innovative goals but limited resources, some employees may pursue these goals without permission. Anecdotal observations, however, reveal underground employee behaviors that do not fit this pattern; underground innovations may serve different purposes and remain permanently invisible. We therefore conducted an explorative study of why and how employees develop underground innovations. Based on interviews and survey data at a multinational automotive company, underground innovations have three orientations: missionary (aimed to change company practices), user (to solve work problems), and exploratory (to cater to developers' passion for exploration). The three orientations differ in their involvement of others, deployed resources, and dissemination efforts. Without missionary orientation, underground innovations are not proactively diffused, inhibiting organizations from reaping their full benefits. We infer a refined theory based on constraints that prevent employees from being openly proactive. Specifically, underground innovation may be triggered by 1. lacking resources to pursue organizational innovation goals, 2. lacking resources and thresholds to improve work processes, and 3. the organization's inability to match work tasks with innovation workers' preferences. The last two constraints are easily overlooked, and organizations will capture more value from their human capital by stimulating the diffusion of user and exploratory-oriented projects.

1. Introduction

It is well known that some employees work on innovations they initiated themselves, *without* informing their managers or organization. Schön (1963) observed that many radical innovations in the US military were initially unsanctioned, developed with funds that employees had detoured from official work tasks. Knight (1967) described innovations developed by employees who lacked decisive power and kept their activities hidden until their innovations became irreversible. Aram (1973) explained the case of a chemical company where the most productive innovations emerged from an "underground system" of workers collaborating on unsanctioned projects. These innovations were all developed "underground" by employees who had not asked their managers or

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organization first. As such, underground innovations differ from formal, sanctioned innovation projects that are generally visible within the organization's innovation management systems, or at least known about and consented to by managers (Augsdörfer, 1996; Globocnik and Salomo, 2015; Mainemelis, 2010).

Bootlegging has emerged as the main field of research concerned with underground innovation. Bootlegging is the process by which individuals take the initiative to work on ideas without formal organizational support, (initially) hidden from senior management, but intended to benefit the company (Augsdörfer, 1996, 2005; Criscuolo et al., 2013). Eventually, employees will reveal bootlegged innovations to realize such organizational benefits (Eicher, 2020; Mainemelis and Sakellariou, 2023). A related concept is creative deviance: employees who violate managerial orders to terminate working on innovations, which they reveal again at a more mature stage (Mainemelis, 2010). Both concepts can be explained with structural strain theory (Merton, 1968). When organizations formulate innovation goals but have insufficient resources to back up all innovative ideas, some employees pursue these goals in "illegitimate" ways (Globocnik and Salomo, 2015; Mainemelis, 2010). Bootlegging and creative deviance enable employees to achieve greater autonomy over their innovation efforts and escape accountability constraints (Criscuolo et al., 2013).

However, a closer look at previous innovation management studies suggests that the current views on underground innovation are incomplete—with implications for its theorizing and the practice of strategic management. For example, studies of user innovation have looked at employees solving work-related problems or challenges (e.g., Wu et al., 2020). It has been observed that employees sometimes innovate without permission, but keep their innovations out of sight – as dissemination is deemed unimportant (Zejnilovic et al., 2016) or organizational rules are violated (Hartmann and Hartmann, 2023). Another example is open-source projects where professionals develop many contributions during work time, without informing their managers (Bitzer and Geishecker, 2010). These observations suggest that underground innovation may be done for multiple purposes and its outcomes do not necessarily become broadly visible. This would imply that structural strain theory is too narrow, and a broader theory capturing all purposes would be merited. Likewise, for the practice of strategic management underground innovations should become visible to reap full benefits – as competitive advantage depends on the ability to deploy valuable and inimitable resources (Barney, 1991) and to sense and seize opportunities (Teece et al., 1997).

In this paper, we conduct explorative research into the nature of underground innovation. As Gioia et al. (2013) recommended we formulated a well-specified but general research question: *Why do employees develop underground innovations, and how?* This question enabled us to account for a broader range of underground innovation purposes and differences in process characteristics, including employees' efforts to reveal.

We define underground innovation as the initiation and development of innovations by employees that are (at least initially) unapproved and developed without official company resources. Our perspective is slightly broader than the usual bootlegging and creative deviance definitions, which add the assumption that innovations are initiated primarily to benefit the company (Criscuolo et al., 2013; Eicher, 2020). The definition acknowledges a gray zone with formal innovation, as underground innovations may be formalized and completed with official resources later (Demir and Knights, 2021; Mainemelis and Sakellariou, 2023). Yet, we exclude innovations that did not pass the ideation phase or that employees develop with managerial consent, like skunkworks (Masoudnia and Szwejczewski, 2012) and contributions to ideation or crowdsourcing challenges (Campos-Blásquez et al., 2020).

We used a mixed-method approach, in which we first interviewed 39 researchers and product developers in a multinational automotive company about their underground innovations. Next, we collected and analyzed survey data from 420 underground innovation projects. Mixed methods are suitable for developing a better understanding of a phenomenon by combining rich and detailed, qualitative data (capturing the complexity and context of a phenomenon) and quantitative methods (adding to the identification and validity of patterns across larger samples). Together, they balance depth and breadth, offer a comprehensive perspective of a phenomenon, and allow for triangulation (Creswell and Clark, 2017).

Our findings show that underground innovations can have three orientations: missionary (whether innovations aim to change company practices), user (address work problems or challenges), and exploratory (cater to developers' passion for exploration). Based on this result we infer a broader theory revolving around proactivity constraints (Parker et al., 2010). Our theory counsels that employees refrain from being openly proactive and innovate underground due to 1. lacking resources to pursue organizational innovation goals, 2. lacking resources and thresholds to improve work processes, and 3. organizational inability to match work tasks with innovation workers' preferences. The three orientations differ in their involvement of others, deployed resources, and dissemination efforts. Highly missionary projects are actively pushed towards organizational acceptance; echoing studies of bootlegging and creative deviance (Globocnik and Salomo, 2015; Mainemelis and Sakellariou, 2023). User and exploratory projects have been overlooked so far, and here the dissemination effort of employees is less or absent - depriving organizations of fully taking advantage of their human capital as a strategic resource (Hatch and Dyer, 2004; Wang and Zatzick, 2019). This has implications for the practice of strategic management. Mining underground innovation requires a dedicated effort such as designing appropriate ideation systems.

2. Literature review

In our research's first, qualitative part, we applied Gioia et al.'s (2013) method. It enables in-depth exploration of a phenomenon for theory building and future measurement. We took Gioia et al.'s (2013) advice to be semi-ignorant about existing literature to avoid confirmation bias. Hence we here discuss existing insights on underground innovation, not to develop hypotheses, but to explain our frame of reference when we started interviewing.

2.1. Structural strain, bootlegging, and creative deviance

The dominant view of why underground innovations exist is based on Merton's (1968) structural strain theory, originally developed to explain deviant behavior like criminality, rebellion, and retreatism. Structural strain theory counsels that nonconforming behavior is related to discrepancies between a social system's prescribed goals and the means available to individuals to pursue these goals. Generally speaking, societies pressure their citizens to become wealthy or successful but do not provide equal opportunities to achieve these goals (think of differences in access to quality education, available jobs, and funding). This discrepancy leads to perceived strain, which makes some individuals walk illegal pathways to accomplish legitimate goals.

In the context of employees in organizations, scholars applied structural strain theory to explain bootlegging (e.g., Globocnik and Salomo, 2015) and creative deviance (e.g., Mainemelis, 2010). It is *"the response of an employee within an organization that seeks innovation but provides limited resources for idea elaboration"* (Globocnik and Salomo, 2015: p. 507). Unlike its original applications in sociology and criminology, structural strain is assumed to drive a rather positive outcome. Emerging innovations are associated with company growth (e.g., Abetti, 1997; Aram, 1973) and better overall innovation performance (Criscuolo et al., 2013). Hence, managers usually passively allow for bootlegging and creative deviance which they know will exist, although not precisely where (Augsdörfer, 2008; Eicher, 2020).

Looking at the state of the art in bootlegging and creative deviance research, scholars have associated various factors with employees' underground innovation behavior. Examples are personality traits like mastery orientation (Tenzer and Yang, 2020) and risk-taking propensity (Globocnik, 2019); job design variables like autonomy (Augsdörfer, 1996; Masoudnia and Szwejczewski, 2012); and contextual variables such as managerial responses (Globocnik, 2019; Globocnik et al., 2022; Lin et al., 2016) and organizational support (Tenzer and Yang, 2020). Moreover, innovations resulting from bootlegging generate positive organization-level outcomes, like fit with corporate strategy (Augsdörfer, 2005) and novelty to the innovation portfolio (Globocnik et al., 2022). Finally, researchers have developed process models on how underground innovations become formalized (Demir and Knights, 2021; Eicher, 2020) or alternate between underground and formalized status (Mainemelis and Sakellariou, 2023). To our knowledge, studies of the broader scope of underground innovation and when these innovations remain invisible have not been done.

2.2. Deviant observations about underground innovation

As mentioned in our introduction, innovation management studies have occasionally reported on underground innovations that do not fit with bootlegging or creative deviance. Scholars who study user innovation describe innovations that individuals develop to address personal or process-related needs (von Hippel, 2005). Employees may also do this to develop solutions when processes are deemed inefficient, information is unavailable, technological solutions are missing, or situational constraints create challenges (Wu et al., 2020). In this literature, Zejnilovic et al. (2016) found that 31 out of 71 interviewees in a telecom company developed innovations that remained largely invisible to their employer; mostly to address work problems or challenges. Likewise, Hartmann and Hartmann (2023) observed >100 innovations that employees in the police and military developed for personal use, including life-saving applications developed by soldiers on international missions and policemen handling road accidents. These innovations were unsanctioned and mostly kept hidden, as their developers feared negative responses from their organization, and wanted to secure continued use.

Open-source innovation refers to the collective development of innovative products or applications that are free to use and openly shared. Communities of individuals voluntarily contribute to these projects (von Krogh and von Hippel, 2006). Open-source software is best known but applications to hardware exist as well (Balka et al., 2010). Perhaps surprisingly, open-source contributions are often made by professionals during work time (Hars and Ou, 2002). Strikingly, professionals frequently do not inform their employers about their involvement (Lakhani and Wolf, 2005; Bitzer and Geishecker, 2010). Their motivation is mostly intrinsic, as they enjoy the process of open development, working with like-minded others, and developing their skills (Lakhani and Wolf, 2005).

User innovation and open-source scholars have not systematically investigated what makes employees innovate with or without managerial permission. Nevertheless, some of their findings indicate that underground innovation is a potentially broader concept and that innovation outcomes may remain invisible to the organization.

2.3. Identifying interview topics

Based on the literature above we identified various topics on which underground innovation may vary. First, it seems that underground innovations can be developed for different purposes. Underground innovations may be initiated for organizational benefits (Criscuolo et al., 2013; Eicher, 2020) but also to fix local, work-related problems (Wu et al., 2020). The open-source literature suggests benefits that employees derive from the innovation process, e.g., enjoyment, intellectual stimulation, or opportunities to develop new skills (Lakhani and Wolf, 2005).

Next, employees may vary in how they involve others and use resources. In bootlegging and creative deviance, for example, employees are known to collaborate informally and use slack time (Augsdörfer, 2008; Criscuolo et al., 2013; Eicher, 2020). Further along the road, they may surface their innovations to claim official company resources (Abetti, 1997; Mainemelis and Sakellariou, 2023). User innovation may as well be done individually without involving others (Baldwin and von Hippel, 2011). Users use slack resources as well. They are bricoleurs working with the means they find in informal settings (von Hippel, 2005). In contrast, collaborative development is the default in open-source projects (Baldwin and von Hippel, 2011).

Moreover, employees' efforts to disseminate underground innovations may vary. When aiming for organizational benefits,

innovations should at some phase be revealed (Eicher, 2020; Mainemelis and Sakellariou, 2023). In contrast, employees may avoid or lack incentives to disseminate when their primary interest is personal use (Hartmann and Hartmann, 2023). In open-source projects revealing is the norm (von Krogh and von Hippel, 2006), but yet, open-source innovations are not necessarily absorbed where professional contributors are employees—depriving organizations of benefits like new knowledge developed in communities (e.g., Dahlander and Wallin, 2006) or complementary product applications (Gambardella et al., 2017).

In sum, underground innovations may be developed for different purposes and with different involvement of others, resources, and dissemination efforts. These were main topics in our interviews (section 3).

3. Interviews

We conducted our research at an automotive firm with global reach. This context resembled most previous studies, which are usually done in large organizations with formalized innovation programs (e.g., Abetti, 1997; Augsdörfer, 2005; Globocnik and Salomo, 2015). The automotive company maintained an extensive innovation strategy, in which formal innovation projects were documented in innovation portfolio databases and stage-gate systems. The company employed many professionals in innovative jobs. In this environment, we could anticipate underground innovations to be present and distinguishable from formal innovation activities. Also, the large company size (>150,000 workers) implied multiple hierarchical layers and some bureaucracy, which was also expected to increase the odds of underground innovation (Hartmann and Hartmann, 2023).

A case study in one organization has limitations, but in our initial exploration, we preferred the benefits of in-depth insights over immediate generalizability. Data on underground innovation are generally challenging to obtain (Augsdörfer, 2005) and our access to the automotive company enabled us to obtain confidential data that would be complicated to get in a multiple-case setting – and this consideration is again consistent with previous studies of underground innovation (e.g., Mainemelis and Sakellariou, 2023).

3.1. Participants and procedure

We interviewed employees from two departments in Germany. The first department was responsible for research of long-term strategic importance; related to powertrains, safety systems, driver assistance systems, vehicle dynamics and chassis technologies. The second department conducted most of the company's product development in Europe.

Interviewees were sought from various sources, to maximize variance in our data (Strauss and Corbin, 1998). First, we consulted our key contacts at the company who had in-depth knowledge of its shopfloor processes—including an internal coordinator concerned with employee innovation, a job coach, and the coordinator of an internal innovation hub where employees were offered tools and informal networking facilities. Upfront we familiarized our key contacts with underground innovation, then asked them to identify suitable participants. Being deeply embedded they could immediately make suggestions, including some employees who had not communicated about their underground projects themselves, but where our contact persons had observed their behavior. Next, our contact persons asked at coffee corners, lunch meetings, and informal networking events if employees had developed underground projects or could nominate relevant others. They also invited their local managers to identify more workers with underground innovations—knowing that some underground projects are communicated and become visible to managers (Eicher, 2020). Finally, we spent multiple days at the company as embedded researchers, asking around at the innovation hub, coffee corners, and lunch facilities, to identify more interviewees.

Asking questions about underground innovation is potentially sensitive, so interviewees were invited with great care (Augsdörfer, 1996; Eicher, 2020). Our contact persons—all keeping highly trustworthy positions—made initial appointments on our behalf, explaining our scientific purpose and assuring full confidentiality. With the help of the job coach, we also cross-checked that our approach aligned with the company's policies and ethical guidelines. This was communicated to interviewees, which facilitated their willingness to collaborate. Fortunately, throughout the company underground innovation was known to exist and not considered negative per se, which helped us to implement our research. Many interviewees were eager to talk about their underground projects.

We conducted 39 interviews. The average interview time was 70 min. Interviewees occupied a range of positions, including supervisor or line manager, researcher, engineer, or otherwise (e.g., buying coordinator, project planner). Their average tenure and age were 12.6 and 41.3 years, respectively. Seven interviewees were female. These demographics were in line with the company's overall demographic profile. See Appendix A for details.

During the interview, we first established rapport by reassuring confidentiality and elaborating on the interviewee's job and involvement in formal innovation. Next, we explained the underground innovation concept as innovations that employees had initiated and developed, at least initially without permission or using official company resources. We also clarified the distinction with formal innovations, defined as projects that management had approved upfront, with a planned budget and timeline, and documented in the organization's formal systems. Next, interviewees indicated if had developed any underground innovations in the past three years. If yes, they were asked to elaborate what they had developed (product or part, process, software, work method, etc.), and what made it an underground project (after some initial interviews, we added the requirement that actual development activities were done, to avoid projects that never passed the ideation phase). In the absence of any underground innovations, we asked if interviewees contributed to colleagues' underground projects in the past three years. Twenty-seven interviewees had developed at least one underground innovation themselves. Another four had contributed to innovations initiated by others.

Our interview script was semi-structured, with an outright focus on our research question: we asked for interviewees' purposes with underground innovation, how they had developed their innovations, and whether they had somehow attempted to disseminate their innovation. As prescribed by Gioia et al. (2013), throughout our data collection we modified our interview script in line with our

emerging discoveries; interviewing and analysis proceeded in parallel. For example, we quickly learned that answers could strongly differ per innovation. For that reason, we focused the interviews on specific underground innovation projects. When interviewees had developed multiple innovations we asked to focus on the first case that was mentioned. Analyzing data about specific innovation projects is uncommon in bootlegging and creative deviance studies, which mostly focus on the individual level (e.g., Criscuolo et al., 2013; Globocnik et al., 2022; Lin et al., 2016). Yet, important nuances would be missed if only generic person-level data had been collected.

Descriptions of the reported underground innovations can be found in Appendix A. All examples were at least initially developed without managerial approval. Some were even never communicated. As mentioned, we excluded examples that had never passed the ideation phase, but required that innovations had been prototyped and put into use, or proposed for organizational acceptance. Examples range from new products and parts (e.g., *"a brake warning system using sensors that indicate overheating of brake pads"*

Fig. 1. Data structure.

(interviewee #17)), technologies (e.g., *"new way to smartly align a car's steering motion with its electronics, like the blinking lights*" (#7)), processes and work methods (e.g., *"I developed a machine to recycle leftover plastics for injection molding"* (#9)), to software (e.g., *"it was a simulation tool for power energy requirements, to optimize cars' energy use"* (#33)).

3.2. Analysis

In the Gioia method, novel theoretical insights are based on an inferential process, departing from inductive reasoning, towards more abductive reasoning by systematically combining emerging field data with existing theory (Magnani and Gioia, 2023). In our analysis, we followed this process by carefully distinguishing between first- and second-order coding (Gioia et al., 2013). The first-order coding resembled open coding (Strauss and Corbin, 1998), and was fully interviewee-centric. We assigned codes respecting our interviewees' vocabulary and avoided imposing existing theoretical concepts. Doing so, we learned that interviewees were talking about their underground innovations in terms of motives and purposes, contributions by others, use of resources, and efforts to disseminate (or reasons not to do so). During this process, the authors of this paper regularly engaged with each other in "interviewing the investigator" to improve the robustness of the emerging codes (Chenail, 2011). While new interview data were added, we did additional iterations of coding, analysis, and discussion, which made us finetune our first-order codes.

Halfway through our interviews, we engaged in second-order coding (axial coding in grounded theory) to classify the first-order codes into second-order themes (Gioia et al., 2013). Here we introduced researcher-centric and more theoretical concepts. We gradually inferred three main purposes of underground innovation: changing a company practice, fixing a work problem, and catering to the developer's passion for exploration. Likewise, we identified common themes in how underground innovators involved others, acquired resources, and disseminated their innovations. Existing literature helped us identify relevant themes but we were careful not to impose theory on our data. For example, we barely found employees who contributed to open-source projects, or who were developing underground projects with communities of practice beyond the company's boundaries. Still, the motivations that are described in the open-source literature helped us to identify the purpose that some employees innovate underground to cater to their passion for exploration and invention—a passion that seemed related to their aspired professional identity. While our interviews progressed, we kept comparing our emerging themes across the growing evidence, refining our data structure. The first- and second-order coding made us understand interviewees' lived experiences and enabled higher-level theorizing.

Emerging with the second-order analysis, we identified aggregate dimensions that explain why and how employees develop underground innovations. Specifically, we identified three orientations: missionary, user, and exploratory. We cross-checked our data structure by adding a few more interviews, searching for confirming and disconfirming evidence. We also presented our preliminary findings to our key contacts at the company plus a group of interested managers and other employees. By then our insights became saturated. Our data structure is shown in Fig. 1.

3.3. Findings

Underground innovations can have three orientations: missionary, user, and exploratory (Table 1). These orientations apply to the innovation level; employees may do underground projects with different orientations. The orientations can also be simultaneously present.

An orientation is a "general or lasting direction of thought, inclination or interest" (Merriam-Webster, 2024). We used the word "orientation" to capture a project's purpose, and the overall approach used to pursue this purpose—how other people are involved, what kind of resources are used, and the dissemination effort that is done. Orientations are primarily defined by their purpose but also capture how innovations are developed and disseminated.

3.3.1. Purposes

Three main purposes of underground innovation identified were: to change a company practice, address a work problem or challenge, and pursue a personal passion for exploration.

Underground projects could be more or less missionary-oriented. This corresponds with a desire to change an organizational practice. Some interviewees were convinced that their innovations were valuable to the organization. They claimed to know better than their superiors and sometimes dared to violate managerial orders or did not bother to ask permission: *"During the development of my virtual reality technologies, I got told many times that I should stop. But I truly believe in the potential of VR and its value for the company"* (#5). Without organizational acceptance these interviewees would regard their project as a failure. Accordingly, they actively promoted their projects: *"It is not about the sheer fun of it. I engage in underground innovation to make a change within the company!"* (#26).

Underground projects also differed in their degree of user orientation, corresponding to fix a local work-related problem or

Table 1
Three orientations of underground innovation projects.

	Missionary	User	Exploratory
Purpose	Change a company practice	Address a work problem	Passion for exploration
Involved others	Company-wide network, many collaborators	Local network/team, few collaborators	Buddies and experts, few collaborators
Resources	Organizational resources, seek new company resources	Informal resources, existing slack	Personal resources, leisure time
Dissemination	Proactive persuasion; high effort and persistence	Passive sharing; low effort or hiding	Showcasing; modest effort

challenge. For example: *"I was increasingly bothered by the limitations of the standard software provided by the company, so I started thinking about extensions I could develop myself. Due to the extensions I developed, my tasks became easier and less time-consuming"* (#34). Highly user-oriented projects sometimes also addressed a problem in the developer's work team: *"I built tools to analyze the crankshaft, piston, and Conrad parts of our cars. These tools were testing if friction could be reduced. We needed these to more efficiently conduct a crankshaft efficiency project*" (#30).

Finally, underground projects were more or less exploratory-oriented, to pursue a passion for exploration and invention. For instance: "*I am not driven by cost reductions or increasing efficiency, not winning a battle for the company. My effort is purely driven by curiosity"* (#7). Developers of these projects regarded the process of innovation as an objective as such. It contributed to their aspired professional identity: *"I am triggered by the challenges I observe in daily life and get excited by the process of developing solutions. It is an inner drive for problem-solving using my technical skills. After all, that is what engineers love to do"* (#7). They strived to develop and practice their skills and were driven by self-actualization: "*I like to maintain and improve my engineering skills. With some buddies at the company, we developed a device to integrate smartphones into the car's touchscreen. It helped me practice my skills. We applied for a patent, not so much for the bonus, but just because it is nice to have"* (#2).

3.3.2. Involvement of others

Underground projects were often developed with the help of colleagues who provided informal assistance or advice: *"Networks of employees, other than the formal teams, are important for this, but not facilitated by the company. You have to initiate them yourself"* (#16). We observed that the three purposes were associated with different kinds of involvement: from regular company networks, nearby colleagues, and informal contacts (buddies and experts throughout the company).

In the more missionary-oriented projects, developers mobilized lots of help from company networks. These overlapped with the people that they would assist with formal innovation activities. They also involved decision-makers and opinion leaders, whom they contacted proactively to improve the odds of organizational acceptance in a later phase. Underground innovators typically expanded their networks within the organization, reaching out to those who could positively influence decision-making processes or provide extra resources. Doing so, they consciously timed their requests while accounting for the internal political environment: *"I chose the right employees to champion my idea. Those I knew management would listen to"* (#10).

In highly user-oriented projects, employees found help in their existing network— colleagues in their work team or others nearby with relevant expertise. Compared to missionary projects, these collaborators were found locally, not at other plants or in other countries. Reaching out further was often not necessary to solve the problem: "*For the training program, I knew some colleagues who are also part-time lecturers. They could easily develop the modules for electrical engineers I needed"* (#4).

In projects that were mainly exploratory, contributions from others were less common. Those who got involved were often like-minded enthusiasts throughout the company, sometimes even in other countries. In these projects employees appreciated working with "buddies" who shared their passion: *"I love to communicate and collaborate with individuals with the same mindset"* (#19). Developing exploratory-oriented projects seemed to contribute to employees' identity—e.g., they often referred to themselves as real engineers or good inventors—and they enjoyed being part of an informal network resembling a community of practice.

3.3.3. Resources

Underground projects were developed with three types of resources: informal, organizational, and personal. The main type, relevant to all three orientations, was informal resources: slack time of the innovator and any colleagues providing help: "*Workload can be quite heavy. Therefore, time to engage in underground innovation is limited during the workweek. In periods where the workload is less, I invest more time in my personal projects"* (#4).

In highly missionary projects, developers were inclined to actively bootstrap additional resources from the organization. They expanded their slack time by amply budgeting their regular tasks, or by leveraging resources from idea management systems: *"I applied to an internal challenge with the software I had already partially developed as if it was still an idea. There I got extra time to further work on it"* (#33). Instead of using the company's ideation and training facilities in their intended way, employees sometimes relabeled their missionary projects to secure extra budgets.

Projects that were mainly user-oriented did not employ other resources than slack. Employees developed these underground innovations in between their official work tasks: *"I just built this animation tool, not sure where I found the time. Having it also saved me time, so then you just do it"* (#35).

Exploratory projects were associated with a different kind of resource: leisure time and even personal income. Some interviewees continued working on underground projects after office hours and over the weekend. They even invested their own money: *"I invested my own money and time to come up with a new machine that could reuse the materials for the plastic injection mold before being reduced to powder"* (#9). Using personal resources was not reported in projects that were only missionary- or user-oriented.

3.3.4. Dissemination

Underground projects differed in how much their developers tried to disseminate their innovations. In highly missionary projects, developers actively informed others. Soon or later they tried hard to persuade decision-makers. Some refrained from revealing innovations too early but rather waited for more favorable circumstances for organizational adoption: "*In my work team, we were already using this facility but did not get official permission. After it was rejected, I waited until my manager got a new position, then applied again and had it approved"* (#25).

User-oriented projects were revealed passively or not at all. Diffusion did occur, but mainly locally when colleagues could observe innovations being used, or when they had contributed to their development. Broader organizational benefits were considered less

important. Interestingly, we heard various arguments to avoid dissemination. Some interviewees feared strict monitoring: *"My manager would blame me for working on projects without his consent and give me extra projects as if I would not have enough at hand"* (#29). Others did not like the anticipated standardization that would come after dissemination: *"If Jim's software would be picked up by the company, he would need to make changes to meet the company's official standards. The implication is that the software no longer does for 100% what Jim wants"* (#3). Another reason was that diffusion would take time; interviewees thought that problem-solving was fun but explaining to others was not. Nevertheless, most interviewees indicated some willingness to reveal more passively: *"Jim sometimes meets with Andreas at the coffee corner. Andreas happens to be more skilled in developing technical solutions. Only after Jim told about some of his problems, Andreas shared the advanced Excel macro he recently wrote"* (#3). Diffusion of user-oriented projects seemed to depend a lot on coincidence: *"Spreading my software extensions was not my intention, I only built them to make my job easier. If the student had not spent the time to show it off, I would probably still be the only one using it"* (#34).

The dissemination effort for exploratory projects was in between. Generally, employees were enthusiastic to showcase their underground innovations to colleagues. This contributed to their sense of self-actualization and aspired identity: *"I show it so that others know; this is what good engineers do"* (#29). Exploratory projects were also submitted to the company's patent office; a positive evaluation was regarded as a form of recognition. Yet, employees would not push exploratory projects further toward organizational acceptance. They sometimes also delayed showcasing; to secure recognition they preferred to develop a full proof-of-concept first. Others wanted to avoid looking incompetent. Sharing a project that may be perceived as low quality, they thought, would give a bad signal about their competencies: *"Naturally, engineers do not want to look incompetent"* (#14).

3.3.5. Dynamic interrelationships

From our data structure, we inferred a grounded model of underground innovation explaining dynamic interrelationships between our second-order themes (Gioia et al., 2013; Magnani and Gioia, 2023). Fig. 2 shows how the purposes and process characteristics of underground innovations are interrelated.

Again, multiple purposes may apply in parallel. For example, one project was meant to solve a work problem (user-oriented) but its developer sensed that his solution was valuable to the whole company and started promoting it (missionary orientation): *"I developed a database application to help me monitor our powertrain research projects. Then I realized everyone at [organization] could use this, so I started pushing it. It is now a company standard"* (#1). The 'and/or' in Fig. 2 indicates that with more purposes, a broader range of people and resources is likely to be involved. Also, the orientations are associated with different levels of expected visibility to the broader organization. The right-hand side of Fig. 2 shows that visibility to the company is less likely when missionary orientation is missing.

We also observed that the dissemination and development efforts of underground innovations were sometimes intertwined. Highly missionary projects were often already revealed to *some* other people at the company while still being developed. This enabled innovators to mobilize additional help and resources, and/or influence decision-makers who would become important later. The simultaneous occurrence of development and diffusion effort is denoted by the two-sided arrows in Fig. 2. For exploratory projects, employees did a similar thing but at a smaller scale. They often revealed their projects to buddies and experts throughout the company, even when those did not provide active help: *"I worked on a new type of airbag compartment, which I discussed with a Brazilian colleague from whom I know he cares about it"* (#7). In contrast, highly user-oriented projects were developed first, and only passively shared later, if at all (denoted by a one-sided arrow in Fig. 2).

Another observation is that the distinction between underground and formal innovation projects is sometimes blurred. This possible overlap mainly applies to missionary projects. Here innovators were inclined to involve their managers at some point: to influence decision-making or secure resources, e.g., *"I prefer to remain under the radar until a proof-of-concept can be shown to increase the odds of implementation. If I would ask permission right away, I would not be allowed to work on it"* (#8). This observation is consistent with bootlegging and creative deviance studies in which underground innovations are more present in the fuzzy front end of the innovation

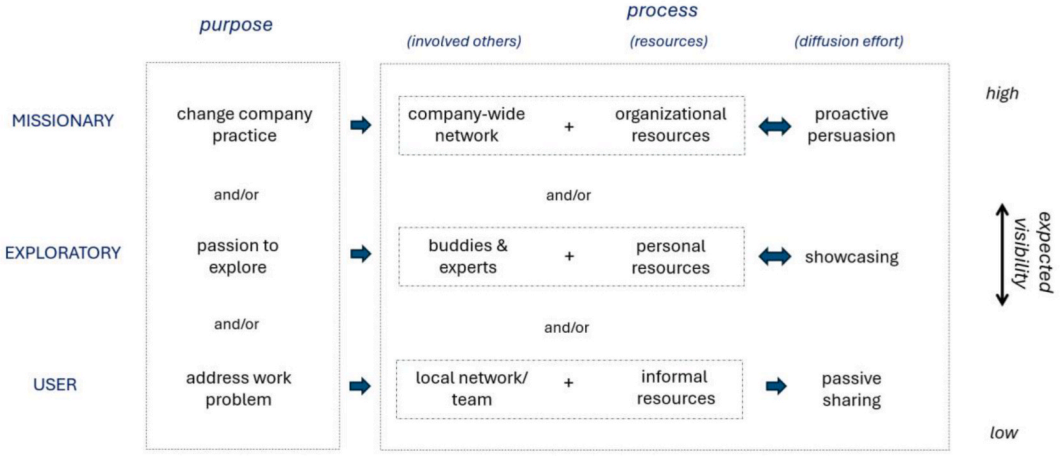

Fig. 2. Grounded model of underground innovation.

process (Augsdörfer, 2008) and more likely to proceed as formal projects (Mainemelis and Sakellariou, 2023).

To illustrate the three orientations and their interrelationships between second-order themes, Table 2 presents cases taken from our interviews.

4. Survey

After our qualitative research, a quantitative phase helped to obtain a more comprehensive view of underground innovation and to triangulate our findings (Creswell and Clark, 2017). We aimed to replicate the three orientations in a larger and broader sample, and possibly finetune our insights.

4.1. Participants and procedure

We surveyed employees at three locations: the two departments where we interviewed and another product development department in the United Kingdom. The sample included R&D workers (researchers, product developers) and support staff concerned with car warranty policies, human resources, administration, IT, and operational support (e.g., operators at test tracks, communication officers, and secretarial workers).

Screening questions were asked to identify if respondents were underground innovators and to select a specific project. Innovation was defined as the development and introduction of new products, technologies, software, processes, or work methods. Then, informal innovation was defined as innovation projects that were at least initially developed without permission or using official company resources. ("Informal" was preferred over "underground" to match our interviewees' vocabulary.) We then asked if respondents had developed an informal innovation project in the past three years. If necessary we asked to select their most recent example to ensure a random sample that was still on top of mind. Next, respondents reported about the purposes of their innovation project, involvement of others, employed resources, and dissemination within the company. We also asked respondents about the object of their innovation (i.e., product, technology, process, or software) and their estimated time spent to learn about the scale and magnitude of underground innovations. The survey is available on request.

We first collected survey data at the research department, using a classical pen-and-paper survey. Over two days, one of the authors of this paper personally handed out the questionnaires. We received 99 responses from 190 employees. These respondents provided

Table 2
Examples of missionary, exploratory, and user-oriented underground innovations.

Orientation (interviewee)	Underground innovation	Purpose	Involved others	Resources	Diffusion effort	Visibility
Missionary (#33)	**Simulation tool.** For power energy requirements, to optimize electric cars' energy usage. The software tool was also linked to other company systems in which energy simulations were useful.	**Change company practice.** R&D worker who thought that the company should have more advanced tooling, given the global trend towards electric vehicles.	**Company-wide network.** Contributions from colleagues with specific coding expertise from other teams, and an external supplier.	**Organizational.** Amply budgeted a formal work task (six months) for which much less time was needed. This enabled expanding her coding skills. Later, an involved manager secured funding for the external supplier.	**Proactive persuasion.** Persuaded her manager first, who helped to influence key decision-makers next. Project was formalized after first prototype.	**High.** A prototype was implemented locally. Currently the tool's user friendliness is improved before company-wide implementation.
Exploratory (#9)	**Plastics processing machine.** To recycle waste from printed car parts. The machine converts leftover materials into a powder that can be used as input for the injection mold.	**Passion to explore. P**roduct developer with a passion to tinker with new technological solutions. His drive was not sustainability, but enthusiasm for the innovation process.	**Innovation buddies and experts.** Received help from two colleagues with the same mindset, encountered at network events. Had weekly informal meetings with these colleagues.	**Personal.** Spent leisure time and private money to prototype the machine. Strongly believes that invention does not stop after work time.	**Showcasing.** Applied to the internal patent office. No further dissemination effort. The developer faced bureaucracy depriving him to disseminate actively.	**Medium.** Patent was granted and now part of the company's patent portfolio. The machine is used locally by the developer and others.
User (#35)	**Animation tool.** Expanded existing CAD software for chassis design: an add-on so that animation features can be used more efficiently.	**Fix a work problem.** Product developer knew from a former job that current software could be expanded. **B**uilt the add-on and put it into use to save time on his next assignments.	**Local network/ team.** Assistance from colleague in the same team to connect the add-on with suspension technology. Another colleague helped testing it.	**Informal.** Developed in slack time, in between formal innovation projects. Anticipated future time-saving motivated developing a good fix.	**Passive sharing.** The innovation was initially used by the two contributors, then adopted by another colleague in the team. Broad spreading did not come to mind.	**Low.** Add-on is currently used in the work team, but not in other teams nor by chassis designers in other countries.

data on 57 underground innovation projects. We used these data to develop multiple-item measures (see hereafter). Next, we distributed an electronic, shorter version of the survey to employees in the other departments. Their general managers first announced the survey, then our contact persons sent a weblink through the organization's e-mail system. We received 830 responses from 3513 employees. They provided data from another 363 underground projects.

Overall, we received 929 responses from 3703 invited employees (25% response rate). Fourteen percent were female. Their average tenure was 15.3 years and their age was 44.7 years. Twenty percent had a bachelor's degree, 61% a master's degree, and 10% a doctorate. The other 9% were less educated. The demographic profile of respondents was in line with the general characteristics of the employees in the three departments.

Out of the 929 survey respondents, 420 reported an underground innovation project. The company's privacy policies kept us from a detailed non-response analysis, but this was not detrimental given that we did not seek to explain heterogeneity in person-level underground innovation, or compare underground innovators with non-innovative employees (as other studies have done, e.g., Globocnik et al., 2022; Lin et al., 2016). To explore the nature of underground innovation we only required a sample of projects with sufficient variance.

4.2. Data

Table 3 shows our variables, including descriptive statistics.

Scope. The projects in our sample were concerned with products (29%), technology/patents (26%), software (32%), and processes/work methods (47%). Multiple answers were possible, as automotive innovations may embody various objects. Respondents also indicated if their project, including contributions by others, had taken hours (15%), days (30%), weeks (29%), months (22%), or years (4%). A more precise question about time spent was not possible, since underground innovations are developed in unadministered

Table 3
Variables (n = 420).

Variable	Description	M	SD
Scope:			
Innovation object	Underground innovation was concerned with a … (multiple answers possible)		
-product	… product or service (0 = no; 1 = yes)	0.29	0.46
-technology	… technology or patent (0 = no; 1 = yes)	0.26	0.44
-software	… software (0 = no; 1 = yes)	0.32	0.47
-process	… process or work method (0 = no; 1 = yes)	0.47	0.50
Time spent	Estimated time spent on the underground innovation (1 = hours, 2 = days, 3 = weeks, 4 = months, 5 = years)	2.71	1.10
Purpose:			
Change company practice	Average of 4 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.75): 'I was very persistent at persuading others about this innovation.' 'I would keep working on this innovation, no matter what others think of it.' 'I put in lots of effort to make this innovation pass organizational roadblocks.' 'I have taken lots of effort to propose the innovation to our formal systems.'	4.79	1.19
Address work problem	Average of 3 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.85): 'Using this innovation enabled me to do new things or to save a lot of time.' 'This innovation very much improved our internal processes.' 'The innovation solved problems in a work process.'	5.00	1.67
Passion for exploration	Average of 3 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.70): 'I highly enjoyed starting with this innovation; as if it were a personal hobby.' 'This innovation was primarily driven by my passion to explore and invent.' 'I worked on this innovation for fun and personal reasons more than anything else.'	5.29	1.15
Involved others:			
Contributors	Number of people who contributed to developing or implementing the innovation	2.80	3.40
Resources:			
Informal	Average of 3 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.79): 'To develop this informal innovation … … I often received help from informal contacts within the company.' … I was regularly supported by innovation 'buddies' at the company.' … Colleagues regularly provided friendly assistance without formal approval.'	4.18	1.48
Organizational	Average of 3 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.72): … I strongly expanded my network within the organization to find resources.' … I creatively managed to find additional time at work.' … I strategically used my knowledge of the decision-making environment to increase the odds of being successful.'	4.21	1.38
Personal	Average of 2 items, rated 1 (totally disagree) to 7 (totally agree) (α = 0.78): … I regularly worked in my leisure time.' … I used personal resources (e.g., income, tools at home).' Informal innovation was adopted by … (1 = none, 2 = few, 3 = many, 4 = all)	3.76	1.75
Dissemination:			
Management	… supervisors or managers	1.67	0.78
Work team	… colleagues in the work team	2.19	1.03
Beyond work team	… colleagues in other teams, plants, or locations	1.79	0.83

Notes: M = mean, SD = standard deviation.

slack time.

Purpose. We developed multiple-item measures about the extent to which projects aimed to change a company practice, address a work-related problem, or cater to developers' passion for exploration. Since existing measures were unavailable, we developed a list of items based on our interviews. We selected items based on our first survey at the research department (available upon request). Reliability values (Cronbach's α) were acceptable (see Table 3).

Next, we explored the criterion validity of our purpose measures, by correlating them with respondents' anticipated added value for the company. In the first survey respondents indicated: *'At the time I started with this innovation, I expected it to generate value for the company'* (1 = not at all, 5 = very much). Based on data from 57 underground projects, the purpose of changing a company practice was positively correlated with anticipated company value ($r = 0.49$, $p < 0.001$), but addressing work problems and passion for exploration were not ($r = 0.14$ and $r = 0.22$, p = n.s.). This result resonated with our interview finding that particularly missionary projects are done for organizational benefit.

Involved others. Respondents reported how many people had worked with them to develop the innovation. On average 2.8 others had contributed.

Resources. We developed multiple-item measures for the extent to which employed resources were informal, organizational, and personal. Again, since existing measures were unavailable we formulated items based on our interviews and tested these in the first wave. Reliability values were acceptable (Table 3).

Dissemination. Respondents indicated if their innovation had been adopted by managers, colleagues in their work team, and other colleagues (1 = none, 2 = few, 3 = many, 4 = all). This question gave us a sense of the extent to which underground innovations diffused, and to whom.

Measurement model. Confirmatory factor analysis showed that our multiple-item measures had acceptable convergent and discriminant validity. All six measures were specified as first-order factors indicated by their corresponding items. Factors were allowed to correlate, while error terms between the items were not. The measurement model had acceptable fit ($\chi^2/df = 2.8$; CFI = 0.92; TLI = 0.90; RMSEA = 0.065). Standardized factor loadings were positive and significant ($b > 0.50$; $p < 0.001$). For all measures, the square root of the average variance extracted exceeded the correlation coefficients with other factors. Also, model fit was better compared to alternative models, including a model in which all items loaded on a single factor ($\chi^2/df = 12.9$; CFI = 0.39; TLI = 0.31; RMSEA = 0.169) and a two-factor model with all motivation items loading on the first factor and resource items loading on the second factor ($\chi^2/df = 10.5$; CFI = 0.52; TLI = 0.45; RMSEA = 0.151).

Differences with formal innovation projects. As another check on the validity of our data we compared the reported underground projects with formal, company-approved innovations that respondents had worked on. The distinction between underground and formal innovation can be blurred (Augsdörfer, 2008), so we wanted to ensure that our data truly included underground innovations. In a different part of the survey we collected data on the most recent formal innovation project that respondents had developed; defined as projects that had been approved in advance, with a budget and timeline, and visible in the company's innovation portfolio. Our respondents provided data on 479 formal innovations.

We compared the reported underground projects (U) with the formal projects (F) on three variables. First, respondents indicated to what extent they regarded developing the innovations to be part of their official job. We applied Yuan and Woodman's (2010)

Table 4
Differences between missionary, user, and exploratory-oriented projects.

Variable	Most important purpose			All	Significance	Contrasts
	Change company practice	Address work problem	Passion for exploration			
	(n = 142)	*(n = 149)*	*(n = 129)*	*(n = 420)*		
Scope:						
Innovation object						
-product	43%	11%	36%	29%	$\chi^2 = 40.55$**	user (−)
-technology	30%	13%	36%	26%	$\chi^2 = 19.88$**	user (−)
-software	23%	40%	32%	32%	$\chi^2 = 10.57$*	user (+), missionary (−)
-process	37%	67%	36%	47%	$\chi^2 = 36.07$**	user (+)
Time spent (range 1–5)	3.01	2.66	2.46	2.71	F = 8.73**	missionary (+)
Involved others:						
Contributors (number)	3.9	2.3	2.1	2.8	F = 11.88**	missionary (+)
Resources (range 1–7):						
Informal	4.34	4.10	4.08	4.18	F = 1.36	–
Organizational	4.58	4.09	3.94	4.21	F = 8.69**	missionary (+)
Personal	3.85	3.30	4.20	3.76	F = 9.83**	exploratory (+), user (−)
Dissemination (range 1–4):						
Management	1.92	1.60	1.48	1.67	F = 12.09**	missionary (+)
Work team	2.33	2.29	1.91	2.19	F = 7.06*	exploratory (−)
Beyond work team	1.96	1.87	1.51	1.76	F = 11.31**	exploratory (−)

Notes: Two-tailed significance **p < .001; *p < .01. Contrasts were analyzed with Tukey's b-test. (+) and (−) indicate higher and lower scores compared to the other groups at p < .05 (two-tailed).

three-item measure for this purpose (e.g., '*Working on this innovation was perfectly in line with my formal job responsibilities'*;1 = totally disagree, 7 = totally agree; α = 0.75). As expected, underground innovations were considered less of a job requirement than formal innovations ($M_U = 4.49$, $M_F = 5.35$, $t = 10.35$, $p < .001$). Second, we compared how many people had contributed to both types of projects. For underground innovations this was significantly less ($M_U = 2.8$ persons, $M_F = 8.0$ persons, $t = 7.60$, $p < .001$). Third, we compared how much time was spent (1 = hours, 2 = days, 3 = weeks, 4 = months, 5 = years). Again, for underground innovations it was much less ($M_U = 2.71$, $M_F = 3.52$, $t = 10.63$, $p < .001$). These differences were in line with expectations: underground innovations fit less with official work tasks and are smaller projects.

4.3. Findings

To analyze if the differences between the three orientations can be replicated in a larger survey sample, we divided the 420 underground projects into three groups - based on their most important purpose (i.e., a project's highest score on the purpose measures). Our dataset then included 142 missionary, 149 user, and 129 exploratory projects.

4.3.1. Differences between the three orientations

Table 4 provides descriptive statistics across the three orientations with an appropriate test of significance (χ^2 or one-way analysis of variance). Since nearly all differences were significant, the right-hand column provides contrast analyses showing how which orientations deviate more specifically.

Table 4 confirms that the three purposes are associated with different levels of involvement of others, types of resources, and dissemination outcomes. Additionally, we found that the three purposes are associated with different objects and time investments.

Missionary-oriented innovations were more voluminous (i.e., involve more people and time), and (although not all significantly different) often focused on developing new products. Using organizational resources is the most distinctive resource. Also, whereas our interviews mainly highlighted that these innovations diffuse through pitching to managers, the survey also revealed relatively strong diffusion outcomes to colleagues in and beyond the work team.

User-oriented innovations were more focused on developing new software and/or processes/work methods. Interestingly, despite our interview results showing that user-oriented projects are revealed the least, their dissemination appeared better compared to exploratory orientations. Likely, by fixing concrete work problems these projects seem more immediately useful to other people in the organization.

Exploratory-oriented projects were most heterogeneous with regard to the objects that were innovated, being evenly distributed over products, technologies, software, and processes. As user-oriented projects, contributions and time spent was lower. The survey did confirm that exploratory-oriented projects are more often done with personal resources. Finally, exploratory-oriented projects disseminate the least, despite employees showcasing these innovations.

4.3.2. Robustness check

Splitting the sample into three groups has the advantage of easy-to-grasp statistics (Table 4), but ignores that the three orientations can simultaneously apply to a single underground project. Hence, we estimated regression models to explore the unique association between orientations and prevailing innovation objects, time spent, involvement of others, deployed resources, and dissemination outcomes. Due to space restrictions we present our models in Appendix B. Our findings were similar.

4.3.3. Refined orientations of underground innovations

Synthesizing our interview and survey data, Table 5 shows the refined orientations of underground innovations. The bottom row adds the most distinctive innovation objects, time invested, and diffusion outcomes based on our survey findings.

5. Discussion

5.1. Conclusions

Our study shows that underground innovations can be initiated for various purposes, each associated with different involvement of other people, use of resources, and effort to disseminate innovations (as summarized in Table 5). Our grounded model explains the various "nuisances" of underground innovation behaviors that we discussed in our introduction.

Table 5
Refined orientations of underground innovations.

	Missionary orientation	User orientation	Exploratory orientation
Purpose of innovation	Change a company practice	Address work problem	Passion for exploration
Involvement of others	Many; company-wide network	Some; local network/team	Lowest; buddies and experts
Distinctive resource	Organizational, seeks new company resources	Only informal resources/slack	Personal; leisure time and personal income
Dissemination effort	Proactive persuasion; high effort and persistence	Passive sharing; low effort or hiding	Showcasing; modest effort
Other characteristics	New products	New processes, software	Miscellaneous objects
	High time investment	Less time spending	Less time spending
	Best adoption, also by managers	Local adoption, mostly colleagues	Lowest adoption rates

Missionary orientation aligns with incumbent thinking about bootlegging and creative deviance (e.g., Augsdörfer, 1996; Mainemelis, 2010). Some underground innovations in our study were initiated with company benefits in mind. Employees made major efforts to mobilize resources, involve others, and accomplish organizational acceptance of such projects—inherent to their intention to change a company practice and create organizational benefits.

User orientation refers to underground innovations to address work-related problems or challenges. This orientation explains the previous observations by Hartmann and Hartmann (2023) and Zejnilovic et al. (2016). When underground projects are (almost) exclusively user-oriented, their developers generally lack incentives to disseminate and often restrict themselves to personally using their solutions. Interestingly, some dissemination did occur, despite developers' marginal effort and low expected visibility (see Fig. 2). Adoption was mostly observed among local colleagues, presumably in better positions to observe user innovations by chance. The more favorable adoption rates compared to exploratory projects suggest that strictly user-oriented innovations embody more (immediate) use value and that organizations can benefit by facilitating further diffusion.

Exploratory orientation is about underground projects that cater to developers' passion for exploration. Some employees even continued working on exploratory projects in their leisure time. They showcased their innovations to confirm their aspired identity, which did not require them to push for broad acceptance. Although the analogy with the open-source literature was not strong, exploratory-oriented projects did resemble some of the behaviors observed in this literature: employees with exploratory projects were highly passionate, eager to connect with like-minded others, and willing to spend their leisure time (Bitzer and Geishecker, 2010; Lakhani and Wolf, 2005).

Altogether, our findings show that the nature of underground innovation is more intricate than bootlegging and creative deviance studies have described so far. Does this imply that previous studies were incomplete? We think not. Rather, previous studies were simply not focused on the potential broader range of underground innovation purposes, some of which are *indirectly* beneficial to the organization. We noticed that user- and exploratory-oriented projects, although not primarily meant to change a company practice, were still deemed advantageous. User-oriented innovations enable employees to do a more efficient or effective job. Exploratory-oriented projects served employees' identity work and kept them highly motivated. Their projects also generated new patents and arguably strengthened the organization's absorptive capacity due to the deeper knowledge base that employees obtained in their field of interest. Importantly, interviewees felt they did not violate their employer's interests. They ensured to do their regular tasks properly and did not report informal projects for strictly private gain, as described in the moonlighting literature (Masoudnia and Szwejczewski, 2012). This all implies that a broader perspective on underground innovation is merited.

5.2. Implications for theory

Our study has two implications: a broadened theory to explain underground innovation, and the insight that investigations at the level of projects are promising.

5.2.1. A theory of proactivity constraints

The variety of orientations (Table 5) show that underground innovation can be triggered by factors other than insufficient resources for company-level goals. Hence, structural strain theory cannot fully explain the emergence of underground innovations. We propose a theory that revolves around constraints that keep employees from being openly proactive.

Our refined theory is based on the analogy with existing literature on employee proactivity. Organizational behavior scholars have recognized that employees may engage in proactive behaviors at work, of which innovation is part (Parker and Bindl, 2016; Parker et al., 2010). Proactivity at work is defined as employees' self-initiated, future-oriented actions, aimed at changing and improving their situation or themselves (Parker et al., 2010). It has also been recognized that employees may focus their proactivity on 1. the strategic level, by influencing their organization's long-term directions (e.g., new market strategies, products, or strategic plans), 2. immediate, task-related improvements (e.g., new methods or processes), and 3. person-job fit (e.g., activities to better align a job with personal competence and preferences) (Parker et al., 2010). Interestingly, the proactivity literature has been silent about whether such behaviors are done with or without managerial approval. Yet, the analogy with our research findings is obvious: missionary, user, and exploratory orientation correspond with proactive strategic, work task, and person-job fit behaviors. This analogy suggests that constraints triggering underground innovation are more diverse.

Our proposed theory includes three proactivity constraints that trigger underground innovation. First, in line with the classical structural strain argument, employees may internalize their company's innovation objectives. When resources are insufficient to support all innovative ideas, employees may prefer to innovate under the radar first, as described in bootlegging and creative deviance studies (Globocnik and Salomo, 2015; Mainemelis, 2010). This constraint results in underground projects that are missionary and that are actively pushed these toward organizational acceptance. It corresponds with Parker et al.'s (2010) proactive strategic behaviors concerned with changing company-level practices, but specifically in situations where organizational resources are insufficient such that employees expect more success from underground efforts.

A second and new proactivity constraint emerges from the objective of organizations to have effective and efficient work processes (Parker and Bindl, 2016). When employees internalize this objective, but resources are insufficient or bureaucratic thresholds are deemed high, employees may rather fix work problems themselves without asking permission. This constraint results in user-oriented projects by employees who may not feel incentivized to reveal their innovations.

A third constraint originates from companies' objective to maximize their human capital coupled with their inability to fully synchronize work tasks with employees' competencies and preferences—while simultaneously, many employees take pride in being good professionals and live up to accompanying standards (Parker and Bindl, 2016). For employees in innovative jobs, like R&D

workers and product developers, it makes sense to develop personal innovation projects to align their tasks with their preferences. This constraint results in underground innovations that are intellectually stimulating, highly explorative, and actively showcased to others to confirm employees' aspired identity.

In summary, our suggested theory combines structural strain arguments (Mainemelis, 2010; Merton, 1968) with views on employee proactivity (Parker et al., 2010). The proposed theory recognizes that more factors may trigger underground innovation. Apart from a company's innovation objectives (Mainemelis, 2010), underground innovation can emerge from other company-relevant goals that employees have internalized: to do jobs the best they can, and to operate at professional standards they are passionate about.

5.2.2. Studying underground innovation at the project level

To research underground innovation it is promising to collect data at the level of underground projects. After initial studies looked at specific cases (Abetti, 1997; Aram, 1973), recent studies mainly collected individual-level data, about employees' aggregated underground innovation behavior. Examples are studies of bootlegging behavior (e.g., Criscuolo et al., 2013; Globocnik and Salomo, 2015), bootlegging tendencies (Globocnik et al., 2022), and creative deviance behavior (Lin et al., 2016). Such measures overlook that employees can develop multiple underground projects with mixed orientations and diverse outcomes.

Project-level approaches will enable a new range of studies of interest for strategic management purposes. For example, researchers can shed light on the conditions under which specific underground innovations become broadly visible. Looking at our three orientations, an obvious next step would be to investigate their interactions, and how this influences the odds of successful development and organization-wide dissemination. Moreover, project-level studies may theorize about new variables not considered here, e.g., how innovations' radicalness or fit with organizational objectives influence their outcomes. Another opportunity is to connect underground innovation with concepts in related fields, for example, on embedded lead users – employees also using their employer's products (Laitio and Nätti, 2023). It is unknown if and when embedded lead users become underground innovators. Finally, multilevel studies can be done in which involvement in multiple underground projects is considered a factor of theoretical interest. For example, hypotheses can be developed about interactions between project-level factors and previously identified person-level antecedents, like risk-taking propensity (Globocnik, 2019) or perceived management support (Lin et al., 2016).

5.3. Implications for practice

For strategic management, the fact that underground innovations have different purposes and may not surface has implications. Visibility and dissemination of underground innovations enable more value capture from human capital, which is a key strategic resource (Hatch and Dyer, 2004; Wang and Zatzick, 2019). As mentioned, previous studies focused on underground innovations to create organizational benefits which are likely revealed at some point (Criscuolo et al., 2013; Eicher, 2020). When missionary orientation is absent, employees' dissemination effort is less – depriving the organization and its members of ready-made solutions or new knowledge.

In daily life, multinational organizations stimulate employee-initiated innovation with ideation systems like suggestion systems (van den Ende et al., 2015) or idea contests (Campos-Blázquez et al., 2020). A key question is whether these systems effectively facilitate revealing underground projects with different orientations. Based on our study, we expect a good match with missionary projects. Ideation systems are generally designed for innovations that benefit the organization (Campos-Blázquez et al., 2020). It is often implicitly assumed that submitters are motivated to fully develop ideas, including changing a company practice. Indeed, in our interviews, employees with missionary projects used the automotive company's ideation systems to obtain additional resources.

To trace and disseminate non-missionary projects ideation systems should be tweaked. For user-oriented projects, scholars identified that users refrain from diffusion because adoption by others, as such, does not compensate for their additional effort (de Jong et al., 2023). This connection may be restored by calling on employees' empathy with colleagues who can benefit from their solution (de Jong et al., 2023). Alternatively, user-oriented innovators may be sensitive to financial bonuses, and the ideation system should minimize their required effort (e.g., delegate continued development to dedicated other workers). Moreover, since the initial diffusion of user-oriented projects is mainly level, ideation systems should allow submissions of solutions that employees observed from their colleagues.

To detect exploratory-oriented innovations we anticipate better results from incentives in line with employees' purpose to cater to their passion and manifest their aspired identity. They would be sensitive to rewards like public recognition and opportunities to meet experts in their field of interest. Ideation systems should resemble beauty contests ('We are looking for prototypes beyond the final frontier!'). As part of the contest, exploratory projects may be showcased (e.g., an internal platform, magazine, or award ceremony), with their developers earning expert recognition. Employees with projects of this kind would also appreciate feedback from like-minded others. This would mean that any involved jury members should be tailored to their submission.

More dissemination of user and exploratory-oriented projects enables value capture from human capital, which is a key strategic resource (Hatch and Dyer, 2004; Wang and Zatzick, 2019). One can expect a diverse strategic impact from mining these projects. User-oriented projects likely add efficiency gains to the company's current processes (e.g., through the invention of more effective software tools) while exploratory-oriented projects are expected to expand the company's knowledge base, and serve longer-term interests – while its outcomes are more unpredictable impact in terms of novelty and value creation potential. In the vocabulary of the ambidextrous organization (O'Reilly III and Tushman, 2013), we expect that dissemination of user-oriented projects will strengthen the exploitation side while exploratory-oriented projects quite obviously shift the balance to exploration. If organizations are forced to prioritize their mining effort, their strategic disposition towards exploitation and exploration becomes important, which for example depends on the importance of R&D in their industry (Uotila et al., 2009).

5.4. Limitations and suggestions

Our study was done in a large organization concerned with research and product development, as in previous studies of bootlegging and creative deviance. Despite this consistency, a recommended follow-up is generalizability. Given their ability to explain all observations of underground innovation reported in previous studies, we expect that our grounded model and refined theory will hold. Context may, however, influence the distribution of underground projects over missionary, user, and exploratory orientations. The theory of proactivity constraints counsels that exploratory projects are barely found in organizations without innovation workers. Their employees will improve person-job fit with other activities than innovation. Likewise, missionary projects may be less present when corporate innovation goals are not prominent, and fewer underground user innovations are expected in flat organizations with low bureaucracy.

Another limitation is that we could not collect objective data about the economic value of underground innovations to the organization. This is an important next step to map the full implications of underground innovation for strategic management. To mention only one example, exploratory-oriented projects may appear to be mostly hobby-ism and not be passively permitted. Although we expect all three orientations to generate company value (e.g., at the automotive company exploratory projects resulted in successful patents and were a strong motivating force), investigating underground innovations' objective outcomes is worthwhile. Managerial or company views on their value would enable us to conclude on optimal dissemination rates of underground projects.

Finally, it remains a challenge to investigate how underground innovations can be detected. In this context, Sakhdari and Bidakhavidi (2016) made the first, qualitative inventory of factors eliciting employees to reveal bootlegged projects. Political struggles may prevent that underground innovations surface, and the impact of contextual factors like management support and rewards seems to vary. We expect that such factors should probably be tailored to the prevailing orientation(s) of underground innovation projects. In section 5.3, we speculated about the potential implications of our findings for the design of ideation systems, but we recommend continuing work on how underground projects can be brought to the surface.

CRediT authorship contribution statement

Jeroen P.J. de Jong: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Max Mulhuijzen:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Brita Schemmann:** Writing – review & editing, Investigation, Formal analysis, Data curation.

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Appendix A. Interviewees

Table A1
Interviewees

	Department	Tenure (years)	Age (years)	Gender	Job description	Underground innovation	Reported project
#1	research	16	43	male	innovation process manager	yes	Powertrain support tool. Software to manage research projects.
#2	prod dev	4	29	male	supervisor internal maker space	yes	Touchscreen integrator. Piece of hardware to attach a smartphone to cars' touchscreens.
#3	prod dev	10	54	male	global product development manager	yes	Reporting software. Automates weekly progress reports.
#4	prod dev	2	25	female	vehicle concepts researcher	yes	Training program. Facilitates maker space use by electrical engineers.
#5	prod dev	7	38	male	software engineer	yes	Visualization tool. Use VR glasses and headsets to visualize the geometry of designs.
#6	prod dev	8	32	male	vehicle architecture engineer	yes	Crash simulation tool. Software to test the effectiveness of new materials.
#7	prod dev	3	36	male	materials engineer	contributor	Steering wheel improvement. Technology enables alignment with car electronics.
#8	prod dev	18	45	male	CAD engineer electrical parts	yes	Breakdown triangle. Self-driving version for autonomous vehicles.
#9	prod dev	7	52	male	buying coordinator	yes	Plastics processing machine. Enables recycling of leftover plastics.
#10	prod dev	14	42	male	senior operator warranty	yes	Innovation board. Work process to assess innovation projects for quality management.

(*continued on next page*)

Table A1 (*continued*)

	Depart-ment	Tenure (years)	Age (years)	Gender	Job description	Underground innovation	Reported project
#11	prod dev	5	29	male	mechanical engineer	yes	Multimedia entertainment feature. Integrated into the car's multimedia system.
#12	prod dev	20	44	male	CAD engineer	yes	Foldable electric bike. Fits a small car.
#13	prod dev	10	35	male	electrical engineer	yes	E-drive system. Integrated into the steering wheel.
#14	prod dev	20	46	male	mechanical engineer	yes	Mobility system. Enables smart use of data that vehicles generate.
#15	prod dev	11	34	female	chassis engineering team leader	no	
#16	prod dev	15	40	male	project planner	yes	Safety belt for children. New buckle system for safety belts.
#17	prod dev	8	38	male	engineer brake systems	yes	Brake warning system. Brake system with a sensor indicating overheating of brake pads
#18	prod dev	18	52	male	engineer cooling systems	no	
#19	prod dev	25	58	male	quality coach/advisor	yes	Blinking simulation tool. Software to test dynamic blinking light patterns.
#20	prod dev	20	47	male	powertrain engineer	yes	Integrated catalysator. Simplified design to reduce CO2 emissions.
#21	prod dev	6	42	male	engineer upper body electronics	yes	Camera driving monitor. Software to apply driver's smartphone as a dashboard camera.
#22	prod dev	4	28	male	software engineer	no	
#23	research	19	45	female	internal coach	yes	Emotional intelligence training program. For engineers and researchers.
#24	research	2	37	male	vehicle systems researcher	no	
#25	research	34	60	female	work council representative	yes	Female engineers panel. Secures female inputs to car design processes.
#26	research	18	40	female	bio-based materials researcher	yes	Material processing technology. Enable degradable materials in the body exterior.
#27	research	14	52	male	combustion engine researcher	contributor	Software application for project management. To support research work organization.
#28	research	19	47	male	manager chassis research	no	
#29	research	5	27	male	vehicle systems researcher	yes	Autonomous vehicle parking. System to enable fully automated parking.
#30	research	16	53	male	powertrain systems researcher	contributor	Crankshaft efficiency tool. Enables testing if friction can be reduced.
#31	research	24	48	male	car lighting researcher	no	
#32	research	1	23	male	tooling lab technician	no	
#33	research	4	34	female	hydraulic systems researcher	yes	Simulation tool for power energy requirements. To optimize cars' energy use.
#34	research	13	36	male	manager lightweight materials	yes	Software improvements. To better analyze applications for lightweight springs.
#35	research	10	36	male	chassis researcher	yes	Animation tool. Expands the existing CAD software for chassis design.
#36	research	19	51	female	portfolio planning manager	yes	Internal makerspace. Initiated and implemented an internal maker space facility.
#37	research	18	43	male	vehicle interior researcher	contributor	Artificial intelligence robot. Helps optimize distance and usage of front desk buttons.
#38	research	21	50	male	quality control supervisor	no	
#39	research	5	40	male	safety researcher	yes	Material standards. Standardized industry coding system for car materials.

Notes: Eight interviewees reported no underground projects. Four interviewees only contributed to others' underground projects.

Appendix B. Robustness check

The correlation coefficients between our variables indicating no problems with common method bias (Table B1). Absolute values of the correlations were mostly <.20. This is smaller than the correlations normally encountered when common method bias is present (Podsakoff et al., 2003). In an exploratory principal component analysis the first factor (Harman's single-factor test) explained only 22% of the variance.

Table B1
Correlation matrix (n = 420)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Change a company practice														
(2)	Solve a work problem	.20**													
(3)	Passion for exploration	.29**	.13*												
(4)	Product	.14**	−.31**	.07											
(5)	Technology	−.02	−.42**	.04	.22**										
(6)	Software	−.08	.19**	.10ˆ	−.22**	−.11ˆ									
(7)	Process	.08	.50**	−.01	−.22**	−.34**	.01								
(8)	Time spent	.31**	.18**	.05	.06	−.06	.09	.09							
(9)	Contributors	.23**	.06	−.04	.15**	.01	−.06	.02	.21**						
(10)	Informal resources	.20**	.09	.02	.16**	.06	−.09	.06	.15*	.29**					
(11)	Organizational resources	.41**	.18**	.10ˆ	.19**	−.08	−.12ˆ	.15**	.32**	.24**	.56**				
(12)	Personal resources	.21**	.07	.31**	.07	.02	.10ˆ	.02	.14*	−.05	.13*	.20**			
(13)	Management adoption	.31**	.15**	.02	.09	−.10ˆ	−.05	.12ˆ	.25**	.22**	.21**	.27**	.00		
(14)	Work team adoption	.25**	.35**	.04	−.11ˆ	−.22**	.12ˆ	.26**	.17**	.19**	.15*	.21**	−.09	.56**	
(15)	Beyond work team adoption	.24**	.22**	−.03	.05	−.09	.04	.12ˆ	.25**	.20**	.13*	.22**	−.01	.49**	.53**

Notes: Two-tailed significance **p < .001; *p < .01, ˆp < .05.

In the regression analyses, we entered the three purposes as independent variables, to control for their mutual relationships. Depending on how the dependent variables were measured, we estimate a probit, ordered probit, or ordinary least squares model (Table B2). All models had a good fit. For example, underground projects in which new products are developed (first column) are positively associated with the purpose of changing a company practice (b = .25, p < .001), negatively with solving a work problem (b = −.29, p < .001), and not with employees' passion for exploration (b = .06, p = n.s.).

Results were basically similar as in Table 4. Missionary orientation is associated with more time invested, more contributions by others, high use of organizational resources, and better adoption by managers. On top of that, the more fine-grained regression analyses confirmed that missionary orientation is also positively related to informal resources and adoption by colleagues in and beyond the work team. Likewise, user orientation is associated less with products and technologies, and more with software and processes/work methods. Adoption outcomes are favorable, especially for colleagues in the innovator's work team. Finally, exploratory projects are most distinctively related to investing personal resources.

Table B2Regression analyses (n = 420)

	(Scope)					(Involved others)
	Product	*Technology*	*Software*	*Process*	*Time spent*	*Contributors*
Regression model	probit	probit	probit	probit	ordered probit	OLS
Effect parameters:						
Change company practice	.25**	.05	−.18*	−.02	.23**	.74**
Address work problem	−.29**	−.35**	.18**	.56**	.06	.05
Passion for exploration	.06	.10	.14ˆ	−.12	−.03	−.34ˆ
Constant	−.67	.23	−1.27*	−2.26**	5 cut-offs	.76
Model fit:						
Overall fit	$\chi^2 = 45.1$**	$\chi^2 = 62.2$**	$\chi^2 = 22.8$**	$\chi^2 = 116.8$**	$\chi^2 = 28.2$**	F = 7.4**
(Pseudo) R^2	.11	.15	.05	.23	.03	.06

Notes: Unstandardized effect parameters are shown. Two-tailed significance **p < .001, *p < .01, ˆp < .05.

Table B2
Regression analyses (continued) (n = 420)

	(Resources)			(Diffusion)		
	Informal	*Organizational*	*Personal*	*Management*	*Work team*	*Beyond team*
Regression model	OLS	OLS	OLS	ordered probit	ordered probit	ordered probit
Effect parameters:						
Change company practice	.26**	.46**	.19ˆ	.36**	.21**	.24**
Address work problem	.05	.09ˆ	.01	.08	.24**	.14*
Passion for exploration	−.07	−.03	.41**	−.11ˆ	−.06	−.12ˆ
Constant	3.03**	1.72**	.63	3 cut-offs	3 cut-offs	3 cut-offs
Model fit:						
Overall fit	F = 6.2**	F = 26.4**	F = 16.3**	$\chi^2 = 53.8$**	$\chi^2 = 67.6$**	$\chi^2 = 42.9$**
(Pseudo) R^2	.05	.18	.11	.06	.07	.05

Notes: Unstandardized effect parameters are shown. Two-tailed significance **p < .001, *p < .01, ˆp < .05.

Data availability

The data that has been used is confidential.

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