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ORIGINAL ARTICLE

Contract labour in mining and occupational health and safety: A critical review

Heather Jackson[1] and Michael Quinlan[2]

[1]School of Health Sciences, College of Health, Medicine and Wellbeing, University of Newcastle, Callaghan, NSW, Australia and [2]School of Management and Governance, University of New South Wales, Sydney, NSW, Australia

Corresponding author: Heather Jackson; Email: heather.jackson@uon.edu.au

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Abstract

In recent decades, there has been a global growth of the use of contract labour in the mining industry, primarily driven by cost/flexibility considerations. At the same time, contracting has been associated with poorer occupational health and safety (OHS) outcomes across a range of industries. Drawing on published research, theses, and government reports, this paper critically reviews the available evidence on the OHS effects of contract labour in mining and the likely implications of further growth in this trend. This evidence confirms that the use of contract labour is associated with worse OHS outcomes, and that the Ten Pathways and Pressure, Disorganisation, and Regulatory failure (PDR) models are both valuable in explaining this. The latter point is confirmed by a more detailed examination of four serious mine incidents in NSW and Queensland. The paper identifies some gaps and areas for further research as well as the actions that mining companies, regulators, and unions could take to improve contractor safety. Notwithstanding the latter, the paper argues that the most effective way of improving contractor safety in mines is reducing the use of contractors overall and concentrating their activities in areas such as major shutdowns/repairs, where contractors have specialised expertise to undertake non-routine tasks. Despite oft-repeated phrases such as zero-harm and management systems, the corporate shift to using contractors is primarily driven by cost-cutting and highlights how OHS is compromised by such priorities.

Keywords: contracts/contractualism; labour relations; non-standard employment; occupational health; occupational safety; vulnerable workers

Introduction

Organisations contracting out activities is both a business and work arrangement. While not new, the practice enjoyed a renaissance that has paralleled, and was indeed encouraged by, the rise of neoliberalism. In mining, contract labour (i.e., worker not employed directly by the mine) dates back centuries, including tribute work in metalliferous mining (whereby groups of workers received a share of the value of ore raised). In coalmining prior to mechanisation coal-hewers were pieceworkers, and in the mid-19th century, Hunter Valley coalminers claimed they were contractors to escape pernicious provisions of the *Master and Servants Act*. While contract labour was used throughout the 20th century in most jurisdictions, workers directly hired by mines remained the dominant mine workforce. But over the past three decades, there has been a

global shift to using contract labour. Emblematic of this contract labour now constitutes more than half the mine workforce in Queensland and Western Australia – two large mining jurisdictions in Australia (Commissioner for Resources Safety and Health 2024). The growth of contracting has also been associated with other shifts in work practices, including the increasing use of fly-in-fly-out (FIFO) and drive-in-drive-out (DIDO), whereby workers live remotely from the mine rather than a nearby mining town and live in barracks while they are on site. While assigned rooms in barracks were the norm, there has been a growing trend to the practice of 'hot-bedding' analogous to hot-desking amongst service workers (Peetz and Murray 2008). The primary drivers for this growth are economic. Contract labour is typically paid less than directly engaged mineworkers. The McKell Report, commissioned by the mining union in Australia, found contractors were paid up to $A30,000 per year less than direct employees (Whelan 2020). Contractors can be more easily 'discharged' in a downturn, and if self-employed will not have access to workers' compensation or other regulatory entitlements, are less likely to be unionised or to raise complaints on-site (Commissioner for Resources Safety and Health 2024).

It is important to note that contracting takes several forms, including episodic (major overhaul and shutdowns), routine maintenance, specialist tasks (e.g., construction, surveying, and pipe installation), and mining operations (specialist mining contractors). Contractors range from small to large firms, and their workers could be self-employed, labour-hire/agency workers, or employees (ongoing or temporary/casual). These variations could be relevant to better understanding the occupational health and safety (OHS) effects of contract labour, but as yet, most research on contract labour is insufficiently differentiated in this regard. At the same time, as we will show, the findings are consistent and match more general research into precarious/non-standard work arrangements covering a wide range of industries, countries, and populations.

Concerns regarding contractors and safety in mining are not new. In 1997, the Western Australia commissioned a report following a spate of fatalities (Western Australian. Prevention of Mining Fatalities Taskforce 1997). This article's aim is to critically review evidence on the OHS effects of contract labour in mining by examining published academic research, government reports, and postgraduate theses, augmented by examination of investigations into four serious incidents involving contractors. Before doing this, it is important to place this research in context by briefly examining the now extensive evidence on the OHS effects of contract labour and other precarious work arrangements more generally. In doing this and in the later examination of mining, we will use two models that provide insights into how and why contracting and precarious work compromise OHS. The next section describes the methods and rationale for the review, including the history of contracting, followed by the review itself. The review examination is subdivided into quantitative (where there are measurable results) and qualitative studies. A third subsection examines research on the links between contracting and undeclared work in poor countries and their importance in terms of global supply chains. We then examine investigations into four arguably typical serious mine incidents in Queensland (Qld) and New South Wales (NSW), providing more forensic insights into how significant elements of Ten Pathways were evident in all four. This is followed by a discussion of the wider implications of and responses to the identified problems and a conclusion.

Contract labour and precarious work in context

The growing use of contract labour in mining should be seen as paralleling a global trend to using these and other precarious work arrangements, including temporary/casual employees, part-time work, home-based/remote work, and dependent self-employment in many industries.

Since the mid-1970s, use of non-standard work arrangements has grown globally, while 'permanent' jobs became less secure due to repeated rounds of downsizing, restructuring, outsourcing, and privatisation. Extensive precarious work, including subcontracting, was not a new phenomenon, although there are new elements, notably digitally-enabled subcontracting, including Uber-style platform work. Precarious work had been widespread during the 19th and early 20th centuries, and indeed the adverse OHS effects of this had been extensively documented (Gregson and Quinlan 2020). Since the mid-1980s, a growing body of research, now amounting to many hundreds of studies using an array of methods, has examined the OHS effects of precarious work and job insecurity. An overwhelming majority of these studies found precarious and insecure work was associated with a diminution of OHS, including higher incidence or frequency rates (hour-exposure weighted) of injuries (including fatalities), poorer physical and mental health indices, and poorer access to regulatory protection – both prevention and workers compensation laws. There was also evidence linking precarious work to sexual harassment, suicide, and drug use, as well as spill-over effects on other workers, healthcare access/screening, and family and community health (LaMontagne et al 2009; Quinlan and Bohle 2008; Quinlan et al 2001). While reviews have identified several gaps (for example, the health effects of subcontracting) and some types of work arrangement appeared to be more hazardous (for example, agency work), the general thrust of the findings was clear.

Research into why/how subcontracting and other types of precarious work undermine OHS is less developed. For the purposes of this paper, we will draw on two models of how work organisation/organisation failure affects OHS that are relevant, one because it came out of examination of incidents in the mining industry even if it applies to other high-hazard industries, namely the Ten Pathways model. The other, a related but more generic model, the Pressure Disorganisation and Regulatory Failure (PDR), has been used in connection with hazardous events but also health-related outcomes amongst a variety of workers (Bohle et al 2017; Quinlan et al 2013; Strauss-Raats 2018). Its three key elements align with arguably the most important elements of Ten Pathways and also have value in understanding how contract labour undermines OHS. Drawing on Reason's (2008) notion of latent failure, a study of 23 multiple and single-fatality incidents in mines in five countries (USA, Australia, New Zealand, Canada, and the UK) between 1992 and 2010 tried to identify if there were pattern failures common to these incidents (Quinlan 2014). It identified 10 pattern failures, some of which were present in every event, with five or more being present in the vast majority of incidents. These 10 pattern failures were design, engineering, and maintenance flaws (1); failure to heed clear warning signals (2); flaws in risk assessment including hazard identification, likelihood/magnitude, controls/monitoring (3); flaws in management systems and changes to work organisation (3); flaws in system auditing (5); economic/production and rewards pressures compromising safety (6); failures in regulatory oversight (7); supervisor and worker expressed concerns prior to the incident (8); poor management/worker communication/trust aka those controlling risk and those at risk (9); and flaws in emergency procedures, rescue, and resources (10). Ten Pathways was confirmed by a number of subsequent studies, including Jackson (2021, 2023) whose examination of investigations into 51 serious mine incidents in NSW found 75% had 5–7 pathways and 25% had 8–10. The study by Jenke et al (2022) using survey and fatality data in Western Australia reached similar conclusions. One strength of the Ten Pathways model is that the failures align with OHS management system requirements found in mine safety legislation in Australia and other jurisdictions such as Sweden.

In addition to mining, Quinlan (2014) showed the organisational failures identified in Ten Pathways were present in serious incidents in other high-hazard workplaces, including aviation, road and maritime transport, manufacturing, chemical processing, and oil rigs. A subsequent paper (Quinlan 2024) concentrated on how subcontracting contributed to these failures and the value of PDR in identifying the critical risk factors. Illustrating the first point, Table 1 summarises six mass-fatality incidents where

Table 1. Six mass-fatal incidents associated with subcontracting using Ten Pathways (adapted from Quinlan, 2024)

Pattern-cause	ValuJet crash 1996 Florida USA	AZF factory fire 2001 Toulouse France	Petrobras oil rig sinking 2001 south Atlantic	Texas City refinery fire 2005 USA	Hangzhou subway collapse 2008 China	Rana Plaza collapse 2013 Bangladesh
Engineering, design, and maintenance flaws	Yes, outsourcing of maintenance (led to later crashes too)	Yes, chemical waste management	Yes, poor design location of safety material	Yes, second best technology used amongst other flaws	Yes, route revisions impacted on design integrity	Yes, building illegally extended
Warning signals ignored	Yes, two previous serious incidents	Yes, history of downgrading conditions of waste storage	Yes, history of large spills from rig	Yes, prior incidents	Yes, many similar incidents	Yes, signs of cracking and previous incidents
Risk-assessment flaws	Yes	Yes, not all risks assessed	Yes	Yes	Yes	Yes
OHSM management flaws	Yes, outsourcing maintenance	Yes, especially multi-tiered subcontracting OHSMS didn't cover all hazards/communicate	Yes, downsizing, poor training and use of contractors*	Yes, Bristish Petroleum's system flawed especially devolution and focus on personal safety	yes fragmented/complex web of disarticulated contracts	Yes
System auditing failures	Yes	Yes	Probably but need more evidence	Yes	Yes	Yes
Economic/ production pressures compromise	Yes, low-cost carrier cost-cutting	Yes, use of subcontractors	Yes, focus on cost-cutting and production	Yes	Yes, govt. cost cutting, subcontractors. Pressured and labourers working 16 hours	Yes, global supply chain driver
Regulatory failure	Yes, the Federal Aviation Administration should have acted sooner	Yes, recommended ban multi-tier subcontracting didn't happen but new laws	Yes, government control/conflict	Yes	Yes, contractor offloaded responsibility and numerous violations	Yes, regulation symbolic and global supply chain pick for this
Supervisor and others concerned	Not investigated but probably no	Yes, re lack of contractor training	Yes, union concerns prior	Not investigated but probably no	Not investigated but probably no	Yes
Poor worker management communication/ trust	Non-union operator and workers' pay for training	yes	Yes, union undermined by subcontractor use	Yes, communication gap between subcontractors and other workers	Yes, reports ignored but clear no mechanisms for raising concerns	Yes, little if any union representation and workers threatened
Emergency and rescue system failures	No	Yes, significant impacts surrounding community law changes made	Yes	Yes	Yes, problematic effectiveness examined in report	Yes

Table 2. Risk factors and spill-over effects in the PDR model

Effort/Reward pressures	Disorganisation	Regulatory failure	Spill-over effects
Insecure jobs (fear of losing job)	Short tenure, inexperience	Poor knowledge of legal rights and obligations	Extra tasks and workload shifting
Contingent, irregular payment	Poor induction, training, and supervision	Limited access to OHS, workers comp rights	Eroded pay, security, and entitlements
Long or irregular work hours	Ineffective procedures and communication	Fractured or disputed legal obligations	Eroded work quality and public health
Multiple jobs/ under-employment	Ineffective OHSMS/ inability to organise	Non-compliance and regulatory oversight (stretched resources)	Work-life conflict (e.g., FIFO)

contracting or subcontracting was a causal factor that significantly contributed to pattern failures. In the 2001 AZF factory fire/explosion in Toulouse, France, subcontracting contributed to most of the Ten Pathway pattern failures, and indeed it was used by an expert witness in the ultimately successful prosecution of the company (Lippel and Thébaud-Mony 2020).

Turning to the PDR model, Table 2 summarises elements of the three risk principal factors. Effort/reward/economic pressures, which closely align to pathway 6 in Ten Pathways, include the pressure workers experience due to job insecurity (typified by labour hire and contractors who can be removed from a site at any time without reason), irregular payment, long or irregular hours, and the taking of multiple jobs to maximise earnings. Disorganisation aligns with pathways 3–5 particularly and includes the additional risks associated with short tenure on the job, inexperience, poor induction, training and supervision, ineffective procedures and communication, ineffective systems, and the inability of workers to organise to better articulate their concerns and protect themselves. Regulatory failure aligns with pathway 7 and pertains to flaws/gaps in legislation, misinformation regarding legal responsibilities, and poor enforcement practices and resources. The final column, spill-over effects, is not part of the PDR model but indicates the potential for failures to affect other workers, families, and the wider community. As noted in the following section, FIFO can have negative effects on family relationships and can also negatively impact mining towns.

In the course of this review, we examine to what extent these risk factors and spill-over effects are identified in connection with the use of contract labour in mining. We turn now to the critical review of research undertaken on the OHS effects of contracting.

Methodology

A literature search was carried out to identify the evidence for poorer safety outcomes associated with contracting, subcontracting and other forms of outsourcing. The literature review includes peer-reviewed articles, theses, and grey literature. The methodology could not be described as a systematic search but represented a mixed approach to identifying relevant literature. The approach included database searches and a review of cited articles. Search terms used were ‘health or safety’ and ‘injury or disease or fatality’ in combination with ‘contractor or subcontractor’ or ‘outsourcing’ or ‘multi-tier subcontracting or supply chains’ or ‘illegal or informal mines’. The industry-specific search words selected to restrict the results were ‘mine or mining industry’. Given ambiguity and inconsistency in use of terms such as contracting and subcontracting in the literature, legislation, and by industry, it was not possible to

refine search terms further, although subcontracting is most typically used in relation to multi-tiered contracting arrangements. For the purposes of the paper, we use these terms interchangeably while acknowledging the need for more refined research sensitive to different types of contracting arrangement. The databases searched included Google Scholar, Science Direct, Ebsco, and Sage. In Science Direct, the search was refined by adding 'notconstruction' and filtering by Journal.

Articles deemed not relevant were excluded by 'Title' and 'Abstract' review. Articles that appeared to be relevant were downloaded, and an initial review was conducted using search terms 'mine or informal mine', 'contracting or subcontracting or outsourcing', and 'injury or fatality'. Articles that did not address injury, fatality, or disease or where forms of outsourcing, including supply chains, were not the article's focus were excluded. Areas of interest included quantitative research linking contracting with injury or disease; qualitative research examining hazards and risks associated with contracting; historical reviews addressing economic drivers of contracting, its impact on occupational health and safety management (OHSM), and regulatory challenges.

Literature search results

After title and abstract review, 120 publications were selected for full text review. A further 55 articles were excluded after the full text review. This was supplemented by other literature, such as key reports and books known to the authors. The final selection of 65 items is summarised in four tables according to their primary focus. Fourteen articles focused on the emergence of contracting and subcontracting and other forms of precarious employment in mining, or put it within a historical context. Fifteen articles reported quantitative research results on comparative injury measures for contractors or subcontractors versus direct employees and owner-operated versus contractor-operated mines. Seventeen articles reported qualitative research results examining reasons for the differential OHS performance based on employment type. A final group of 19 publications is a mix of cross-sectional studies and reviews on artisanal and small-scale mining in developing economies and the global supply chain.

Historical context

Research reviewing the historical political and economic reasons behind the emergence of contracting labour is summarised in Table 3. This research identifies that economic drivers associated with fluctuating commodity prices and the emergence of neoliberal politics are two of the key drivers. The literature notes the growth of contracting in the 1990s in South Africa, the United States of America (USA), Commonwealth countries, and Turkey. Fall in commodity prices and a drive to cut labour costs through restructuring of the mining industry are common economic and political themes. Several authors also identified a decline in union representation and inadequate regulation of contracting arrangements and the integration of artisanal and small-scale mining into the global economy (Vingård and Elgstrand 2013).

Several key observations are worth highlighting. Lamare et al (2015), based on their case study on the Pike River coal mine explosion, argued that independent contractors, rather than being independent, are dependent on the mine owner but operate in the market, not within the boundaries of the mine's occupational health and safety management system (OHSMS), and have little protection via legislation. In the petroleum industry, Osmundsen et al (2008) highlighted the problems that contracting poses for safety incentive schemes, and Mills and Koliba (2015) observed that voluntary OHS programs require regulatory bodies to have the technical capacity to oversee complex

Table 3. The emergence of subcontracting in developed economies

References	Country	Study type	Drivers and impact sub/contracting and other forms of precarious employment.
Kenny and Bezuidenhout (1999)	South Africa	Analysis of historical sources and records of interviews with contractors and focus group interviews with mineworkers. Focus on employment conditions (not safety outcomes).	In response to regulations to protect worker rights, subcontracted labour grew from 5% in 1987 to 16% by 1994. Subcontracting is implemented to cut labour costs in a context of declining profits. Contracting in core underground mines circumvents union organisation.
Crush, Ulicki, Tseane, and Van Veuren (2001)	South Africa	Historical review	Stagnant gold prices, declining reserves, and escalating costs throughout the 1990s led to major restructuring, including mine closures, mass retrenchment, the growth of full-calendar operations (fulco), and subcontracting operations (more prevalent at marginal mines where subcontracting is growing faster). • New contractors employed retrenched workers who performed the same work for less money. • Production bonuses make up a portion of the pay, but some subcontractors claim these are rarely paid. • Retrenchments and subcontracting have contributed to the decline in union membership and militancy.
Ehrlich, Montgomery, Akugizibwe, and Gonsalves (2017)	South Africa	Analysis of changing employment practices in the mining industry. Miners recruited between 1973 and 2013 by a major recruiting agency for the mines since 1901.	Major trends relevant to health projection included • a decline in gold mining employment; • the major source of silicosis; • increasing recruitment of female miners; • and shifts in recruitment from foreign to South African miners and from company employees to contractors. The burden of mining lung disease transferred to home communities, as miners, particularly from the gold sector, left the industry. The increase in contract workers and women has implications for health and health services.

(*Continued*)

Table 3. (*Continued*)

References	Country	Study type	Drivers and impact sub/contracting and other forms of precarious employment.
Bester (2022)	South Africa	Cross-sectional – semi-structured interview with participants recruited using purposive and snowballing sampling. The study aimed to develop a corporate social responsibility framework (CSR).	The fall of Apartheid after 1994 and the closure of state mines resulted in retrenchments and the growth of artisanal small-scale gold mines (ASGM). • Legislation was implemented to formalise ASGM but focused on granting legal titles and benefited large mining companies. • Formalisation perceived by artisanal miners as a means of coercion and control. • Industrialised mining offers riches to a select few on the backbone of black labourers. CSR offers a means for mining companies to engage with ASGMs to improve conditions in the informal sector. Abandoned mines could be re-furbished for ASGM but are reluctant as mining companies remain responsible for environmental and H&S hazards.
Johnstone, Mayhew, and Quinlan (2000)	Australia and United States of America (USA)	Historical review of regulation under OHS legislation and arbitration award system, and control of government contracts in Australia and the United States	23 of 29 studies since 1984 found negative OHS outcomes associated with contracting, and 6 were indeterminant. In the 5 years of 1991–1995, the fatal injury rate per 200,000 employees in metal and nonmetal mining was 0.02 for mine operator employees and 0.07 amongst employees of independent contractors, i.e., more than three times higher. Regulating outsourced labour poses a problem for OHS regulators in both Australia and the United States. Issues include (1) multi-employer worksites and (2) dangerous forms of work disorganisation, and ambiguous legal responsibilities.
Barry and Waring (2001)	Australia	Analysis of enterprise agreements	Contracting introduced to address competitive disadvantage is linked to a fall in coal price. Percent of agreements giving management unrestricted prerogative to employ contractors increased from negligible in 1995 to 56% in 1999 and 46% in 2000.
Bowden (2004)	Australia and Canada	Historical review	Locational disadvantage has shaped the use of contractors in the export coalfields of Queensland (Australia) and western Canada since the late 1960s. • Queensland – the use of contractors rose from insignificant to over one-third of the workforce in response to falling coal prices. Increase in subcontractors to address competitive disadvantage linked to fall in coal price. • Canada – the government invested in transport infrastructure to overcome the locational disadvantage, but pits continued with direct employees.

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Table 3. (*Continued*)

References	Country	Study type	Drivers and impact sub/contracting and other forms of precarious employment.
Lamare et al (2015)	New Zealand	Critical case study – evidence reported in the Pike River Mine Royal Commission of Inquiry and the government's internal inquiry; conversations with the key informants, including family and friends.	Specialist contractors, rather than being independent, are dependent on the mine becoming the latest 'vulnerable worker'. They operate in the market, not within the boundaries of the company OHSMS, and have little protection via legislation.
Marriott (2008)	South Africa	Case study – in-depth interviews with informal workers from two small scale mines in KwaZulu-Natal.	Institutional gaps exist in the provision of work health and safety protection to informal self-employed workers. Laws are inflexible towards meeting the challenges presented by informal work.
Stewart et al (2020)	South Africa	Review of empirical studies conducted over two decades, employing a range of research methodologies.	Illegal mining is described as an insurgent globalisation from below. It is both a local and global affair, and it largely occurs in declining gold mining areas, and global crime networks are central to sustaining illegal mining. • Reported deaths of illegal miners in 2009 equalled deaths in the legal formal mining sector. Injuries are not reported in order not to impact production bonuses and be subjected to penalties. • Subcontracting, illegal mining, and inter-union rivalry impact negatively on the mechanisms regulating safety and occupational health.
Osmundsen et al (2008)	Norway (petroleum)	Discursive	Contracting poses problems for safety incentive schemes. • May undermine major accident prevention – A job completed without lost time injuries (LTIs) may attract a bonus, but this does reflect exposure to high-consequence risks. • Contractor safety practices on high-risk jobs may not be visible to the principal (moral hazard), and safety performance indicators for such practices are difficult to identify. • The greater the contractor's share of incident and injury risk, the stronger their focus on safety – contractors may neutralise this incentive by taking out insurance and sharing the risk vertically with partners in the value chain.

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Table 3. (*Continued*)

References	Country	Study type	Drivers and impact sub/contracting and other forms of precarious employment.
Mills and Koliba (2015)	International (petroleum)	Critical case study on Deepwater Horizon case selected to examine market, democratic, administrative, and accountability frames in regulatory regimes.	Decisions made by BP and its contractors • reveal breakdowns and trade-offs in accountability under voluntary OHSMS; • were market driven, i.e., reduced time and achieved short-term operational efficiencies, but failed to consider the long-term reputational and profitability implications of not conducting a risk analysis of its decisions; Voluntary OHSMS programs require professional capacity within the regulatory agency to oversee the complex processes.
Vingård and Elgstrand (2013)	Mining nations	Anthology on safety and health in mineral mining in 16 countries accounting for 65% of world mineral production.	• Chile – large gap in OHS performance between big companies and small and medium-sized companies. Subcontracted miners have a high level of mortality (Herrera-Moreno, 2013). • Turkey – widespread application of subcontracting and outsourcing, which undermines unionisation and hinders OHSM. Subcontracting should be strictly regulated and be banned in core mining activities (Demiral & Ertürk, 2013). • Brazil – observe an increase in subcontracting with a negative impact on OSHM. Trade unionists allege subcontracting weakens the legislative worker protections (authors noted the available data does not permit this hypothesis to be evaluated) (Parreiras de Faria & Dwyer, 2013).
Küçük and Ilgaz (2015)	Turkey	Discursive	The death rate per 100,000 tonnes in private/illegal pits was 2.82 compared to 0.23 in Turkish Hard Coal Authority pits (TTK) pits (timeframe not stated). Technical reasons and distal causes of mining incidents after privatisation include: • subcontracting, sub-employing, and production pressure; • privatisation and royalty system inadvertently promote illegal mining. • lack of accident, injury, and disease records, and loss of collective memory required to prevent incidents.

engineered processes. In South Africa, Bester (2022) argued that industrialised mining benefits a select few, earned on the backbone of black labourers, and Stewart et al (2020) described illegal mining as an insurgent form of globalisation from below.

The remainder of the literature review is presented in two sections. The first section summarises comparative quantitative research on OHS outcomes for direct employees and contract or subcontract workers (Table 4) and owner-operated versus contract-operated mines (Table 5). This research looks at statistical evidence that confirms (or not) the view that contracting results in more adverse health and safety outcomes for workers, focusing on traditional forms of contracting and subcontracting that emerged after 1990. Qualitative research examining why this may be so is summarised in Table 6. The second section reviews the literature on the emergence of artisanal and small-scale (gold) mining (ASM/ASGM) in developing economies and its relationships with large corporate miners and the global supply chain. This literature identifies new forms of precarious employment and exploitation linked to sustainability and the low-carbon economy.

Adverse impacts of contracting

Quantitative research

Only 15 articles undertook a quantitative analysis of contractor and subcontractor and direct employee fatalities or injuries using measures such as injury rates or odds ratios.[1] Nine of eleven studies listed in Table 4, which examine contractor and subcontractor versus direct employee injuries and fatalities, found contractors and subcontractors, or specific types of contractors, had worse OHS outcomes compared to direct employees. A further three studies examined the comparative performance of owner-operated versus contractor-operated mines. These studies found differential performance based on mine size, contract company size, and sector (see Table 5). The fourth study in Table 5 calculated the cost savings for mine holders associated with regaining direct control of their operations.

To assist the reader in interpreting the findings, the following problems with inconsistent terminology and data quality are identified. Firstly, different countries and authors use different terminologies to describe contracting arrangements. The literature review by Nygren et al (2017) noted the term 'contractor' is used in a variety of ways in research and pointed to the need for more precise terminology. In the USA, researchers use the terms 'operator' to refer to a mine operator who is the mine holder and well as a worker directly employed by an operator. The term 'contractor' refers to a company contracted by the mine holder to operate a mine, a worker employed by a contract-operator, and an independent contractor engaged to work at a mine. This distinction is sometimes unclear, as is the case with the article by Muzaffar et al (2013). In Australia, the term 'owner-operator' is used to refer to a company that is both the mine holder and the mine operator, and contractor may refer to both a contract-operator and a worker contracted to work at a mine, whether the worker is employed by the mine owner-operator or a contract-operator. As outlined by Nygren et al (2017), the term contractor describes several different types of workers, including outsourced production workers; maintenance and other service contractors; and workers, technicians, and engineers engaged to perform specific tasks. Buessing (2014) differentiated between these different types of contractors and calculated injury/fatality likelihoods for each type.

The second issue relates to data quality. Swedish authors Blank et al (1995) concluded that *'official statistics do not reflect the real risk situation due to lack of valid exposure data for contractors'* p 34. Several authors in the USA also identified gaps in data collected by the US Mine Safety and Health Administration (MSHA), making the comparison of direct employee and contractor injury rates problematic. The MSHA employment database does not collect hours worked by contractors at specific mines, and not all 'operators'

Table 4. Quantitative research: Sub/contract injury/fatality versus direct employee comparison

References	Country	Sample and method	Data quality issues	Adverse effect of contracting
Blank et al (1995)	Sweden	Cross-sectional – Swedish National Information System on Occupational Injuries Statistical analysis – comparison of mean incidents among contractors and direct employees based on 2,397 accidents between Jan 1986 and Dec 1990.	Due to incomplete exposure for all contractor information, i.e., hours worked, no comparison of direct employee and contractor accident rates is made.	Exposure data available for 1989 showed a contractor accident rate 1.7 times higher than direct employees. There is some evidence that contractors incur more frequent and more severe injuries compared to direct employees.
Cummings and Kreiss (2008)	USA	Commentary, Journal of American Medical Association.	Cited unpublished National Institute for Occupational Safety and Health data.	Preliminary analysis of NIOSH 2000–2004 surveillance data showed that contract coal mine workers with at least 15 years' tenure had a higher prevalence of radiographic changes of pneumoconiosis than the comparable group of noncontract underground coal miners.
Page (2009)	USA	Cross-sectional – MSHA Teradata databases of mine accidents reported by mine operators and independent contractors working on mine property.	Analysed impact of mine size and corporate diversification on accident rates, but not the impact of work arrangements.	Larger mines are safer than smaller mines, and mines with less task diversity are safer than mines with greater task diversity.
Pappas and Mark (2011)	USA	Cross-sectional – Study 1 – MSHA injury data for underground coal contract operators and owner operators between 1983 and 2009. Calculated injury rate based on number of injuries for every 200,000 hours worked; Study 2 – Detailed analysis of injuries and estimated contractor hours in 10 large underground coal mines between 1992 and 2007.	The US Mine Safety and Health Administration (MSHA) database does not assign contractor hours to the individual mining operations where they worked; therefore, the effect of the increasing numbers of contract workers in underground coal mines is unknown.	Study 1 – Trend analysis showed contract-operated coal mine and owner-operated coal mine injury rates have converged since 2005. Larger contract-operated underground coal mines tended to have higher injury rates than the smaller contract-operated mines. Study 2 – Using more accurate exposure data for 10 mines, the study showed higher contractor injury rates compared to direct employees.
Muzaffar et al (2013)	USA	Cross-sectional – MSHA data submitted for operators and contractors between 1998 and 2007. Logistic regression and odds ratios for 157,410 (14,634 contractors and 142,776 operators) of 165,772 incidents that met inclusion criteria. Modelling controlled for other potential explanatory factors.	'Operator' and 'contractor' not defined, i.e., workers or companies. Authors noted models did not include person years of exposure. Reporting differences – results may reflect less frequent reporting of non-fatal events by contractors than by operators rather than increased odds of fatal injuries among contractors compared to non-fatal incidents.	The univariate model for fatalities was 2.8 times higher for contractors than operators (more pronounced in surface mines). The multivariable model showed fatality was associated with contracted labour, less experience at the current mine, and occurrence at more than 8 h into the workday ($P < 0.05$ for each).

(*Continued*)

Table 4. (*Continued*)

References	Country	Sample and method	Data quality issues	Adverse effect of contracting
Buessing (2014) Thesis	USA	Cross-sectional – MSHA employment database and injury database. The MSHA employment database does not capture the presence of contractors at a mine in a quarter unless the contractor is issued a citation during an inspection. Therefore, mines with and without contractor citations are analysed. Statistical analysis by modelling – controlled for time trends, hours, production output, mine geographic effects and geologic characteristics (number of coal beds and average thickness of coal seams), union status, use of specialised capital equipment, and operation type.	The author noted a bias is introduced due to inconsistent reporting of contractor utilisation. Mines with more contractor violations produced more coal; had a larger workforce; used more capital equipment; were older and active for longer periods of time.	Contractors (overall) had fewer injuries than operators (after controlling other variables). By type of contractor – 'riskier' contractors (e.g., construction, blasting) have more injuries than operators (direct employees). Mine-level – (1) mines that use contractors have more injuries and fatalities than those that do not; (2) mines with one or more contractor violations have more injuries than mines with no contractor violations; (3) traumatic injuries were almost five times more likely among mines with one or more contractor violations. Company-level analysis – companies doing day-to-day extraction operations are associated with higher injury measures.
Friedman et al (2019)	USA	Cross-sectional study on long working hour injuries, defined as incidents occurring nine or more hours after shift start. MSHA injury data 1983–2015 – sample of 545,539 incidents with serious injuries involving workers over 18 years. (excluded gradual onset injuries and those deemed not work-related).	Data relies on employer reporting of injuries and illnesses (employers in the mining under-report injuries and illnesses to MSHA, and under-reporting is more pronounced among smaller operators). Cumulative long work hours (over a working week) were not available in the MSHA data, and total hours employees worked 9+ hours were estimated.	9.6% of all injuries occurred during long working hours. 73.3% of those injured were employed by contractors. Risk factors associated with long working hour injuries included irregular shift starts, being newly employed, employment by a contractor, metal/non-metal operations, and mines with <100 employees.
Amoako, Buaba, and Brickey (2020)		MSHA accidents and injury data from 2008 to 2017 Multiclass logistic regression to determine the likelihood of three classes of injury and the influence of independent variables, including employment type.	The authors (1) noted the analysis was not correctly weighted for mine type (coal vs. non-coal) and (2) did not discuss the issue of contractor reporting.	Contractors are more likely to sustain fatal or permanently disabling injuries than operators.

(*Continued*)

Table 4. (*Continued*)

References	Country	Sample and method	Data quality issues	Adverse effect of contracting
Charles, Johnson, Stephens Jr, and Lee (2022)	USA	MSHA injury data and global commodity price. Short-term variation in global commodity prices is used as a measure of demand shocks. Analysis by regression models.	Injury and illness, and mine employment databases do not include severity measures or tenure for contractors, which are used in robustness checks. Mine employment database does not include use of contract labour. If a large portion of injuries involve contractors, then injury rates would be overestimated as the denominator (contractor hours worked) is underestimated.	Injuries and illnesses and safety regulation noncompliance all increase when mines experience positive demand shocks. This is not associated with changes in workforce composition or changes in worker reporting. Incidents involving contractors and not involving contractors were 9% and 8% higher, respectively, when commodity prices increased. Change in contract labour does not fully explain the increase in injuries.
Stemn (2019)	South Africa/ Ghana	Cross-sectional – convenience sample of 5 large mines (out of possible 12). Analysis of 202 incident investigation reports between 2008 and 2017 using descriptive statistics, including employment type, i.e., contractor or operator.	A convenience sample may not be representative.	Contractors represented 23% of the workforce. Almost one-third of contractor injuries were fatal compared to 10% of operator injuries.
Arratia-Solar and Paredes (2023)	Chile/ copper mines	Cross-sectional of commodity price and fatalities in copper mining – Geology and Mining Service of the Chilean Government's employment data and fatal accidents per year by region for the ten years 2010–2019.	None identified by the authors.	Contractors experience higher accident rates compared to direct employees. Fatality trends in contractors are relatively stable over time, while direct employee trends fluctuate with commodity prices. Fatalities have a statistically significant positive correlation with the international copper price in large mining corporations (but not medium- and small-sized operations). Contractors work longer hours than direct employees and in more hazardous environments. (Cademartori 2002). 72% of fatalities occurred in small and medium-sized enterprises, and 50% were workers employed less than a year in their company.

Table 5. Owner-operated versus contract-operated mines

References	Country	Sample and method	Data issues	Safety performance of operations
Dunlop (2004)	Australia	Case study – 10 cases examining the profitability gains of the transition from contract operated to owner-operated mining.		Cost savings from transitioning to contract-operation was 14% (perceived contractor's margin and risk premium). Owner-operator absorbs the risk previously borne by the contract-operator.
Karra (2005)	USA	Cross-sectional study MSHA data of injuries and fatalities 1983–2002 for Non-Coal Contractor, Metal Operator, Non Metal Operator, Stone Operator, Sand and Gravel Operator, and Coal Contractor. Statistical analysis using Poisson regression of injury and fatality rates based on 100 full-time employees or 200,000 employee hours.	Focused on mine operation type, including commodity sector and operator – i.e., owner- or contractor-operator. Did not examine employment type. Does not consider differences in proportion of contract workers compared to direct employees in calculation of injury/fatality rates given MSHA employment database issues.	Injuries – using the coal owner-operator mean injury rate as the reference, coal contract- and non-coal contract-operator rates are 1.41% and 30.34% lower, respectively, and metal owner-operator and non-metal owner-operator rates are 27.18% and 37.51%, lower respectively. Fatalities – using the coal owner-operator mean fatality rate as the reference, coal contract-operator and non-coal contract-operator rates are 129.54% and 234.81%, higher respectively.
Coleman and Kerkering (2007)	USA	Cross-sectional study – MSHA workdays lost data between 2000 and 2004 for coal mine owner-operators, coal mine contract-operators, metal/nonmetal owner-operators, and metal/nonmetal contract-operators.	Used 'days lost' instead of rates to compare mine performance. Did not consider the influence of mine or company size.	Owner-operated coal mines had 1.5 to 2.0 more lost time work cases greater than 10 days compared to average days lost for other sectors.
Buessing and Boden (2016)	USA	Cross-sectional study – all active Kentucky underground coal mines from 1999 through 2013. MSHA traumatic injuries and SHA enforcement databases. Statistical analysis – incident count data analysed by negative binomial regression.	Several other data sets were used to identify contract and owner-operated mines between 1999 and 2013. Considered company size. An interaction between contractor status and the size category of the mining operation allows the contractor effect to vary by size. Fixed effects for time and MSHA district.	Small contractor-operated mines (15 or fewer full-time equivalent workers) had a statistically significant (57%) higher compared to similar mines without contract operators. Larger contractor-operated mines did not have a statistically significant higher traumatic injury rate compared to similar mines that were not contractor-operated.

accurately report the number of contractors working on their mine site. The lack of exposure data for sub/contractors means that calculating comparative injury rates is problematic. The authors dealt with data quality issues in various ways, as described in Table 4 under the 'data issues' column.

Finally, some authors raised the issue of underreporting by contractors (mine level) and smaller mines or contractor companies (industry level) (Muzaffar et al 2013). This may mean the number of contractor injuries/fatalities is underestimated (Blank et al 1995; Friedman et al 2019; Muzaffar et al 2013). Contract companies may also report to their industry sector rather than the mining sector (Blank et al 1995).

Studies also found mine or company size (Arratia-Solar and Paredes 2023; Page 2009; Pappas and Mark 2011) and level of risk exposure (Buessing 2014) affected injury measures. Buessing (2014) found mines with more contractor citations had higher injury measures. Friedman et al (2019) found being a contractor was a risk factor for injuries associated with long working hours. Charles et al (2022) found that change in workforce composition in response to increased market demand did not account for the observed higher injury odds ratios associated with price increases. Arratia-Solar and Paredes (2023) found that contractors employed in copper mining had higher fatality rates than direct employees, but direct employee fatalities in larger mines fluctuated with the copper price while contractor fatality trends remained steady.

Research focusing on mine operators is summarised in Table 5. Two studies found that owner-operated coal mines had higher injury rates than contract-operated coal mines and all mines in other sectors. However, a third study found small contract-operated underground coal mines had higher traumatic injury rates than similar-sized owner-operated mines, but there was no significant difference in traumatic injury rates for larger underground coal mines. Karra (2005) did not consider the proportion of contract workers at contract- and owner-operated mines, and Coleman and Kerkering (2007) did not consider mine size. Charles et al (2022) warned that due to lack of accurate data on contractor hours worked, if a large portion of injuries involved contractors, '*injury rates would be too high since the denominator is too small*' p. 25.

Qualitative research

Table 6 summarises research examining why contractors and subcontractors may experience more injuries and fatalities than direct employees. The PDR models capture many of the causal and contributing factors identified by this body of research, namely production or reward pressures; OHSM disorganisation, including unclear roles and responsibilities, fragmentation of supervision, lack of risk assessment, poor consultation, and perceived negative consequences attached to reporting incidents or concerns; and regulatory challenges. Bahn (2012) and Bahn and Rainnie (2013), however, present a mixed picture of advantages and disadvantages associated with subcontracting labour. They argue that the contract mine operator's OHSMSs are in some instances better than the mine owner's, but note the complexities associated with using a mix of subcontractors and direct employees.

Illegal or informal mining at the bottom of the global supply chain

As described in Table 3, changes in the political, economic, and social landscapes in developing economies and the privatisation of the mining industry contributed to the emergence of ASM and ASGM. Table 7 summarises research on small-scale mining in developing economies. Robles et al (2022) noted ASGMs produce a 5th of world gold but 70%-80% operate outside government regulation. Several authors observed that government attempts to 'formalise' illegal/informal mining have further marginalised

Table 6. Qualitative research: Reasons for adverse effect of contracting or subcontracting on OHSM

References	Country	Sample and method	Health and safety outcomes or adverse effect of contracting on OHSM
Shaw, Blewett, Stiller et al (2007)	Australia	Cross-sectional – multi-method study design including claims, injury, and incident statistics; audit results; regulatory compliance and enforcement data; and mine OHSMS document review. Safety culture questionnaire and focus group interviews.	Contractors work longer hours (51.86) compared to direct employees (50.12) across the industry, which is largest in the metalliferous sector (65.85 compared with 52.40). Fly-In-Fly-Out or Drive-In-Drive-Out rosters favoured working more consecutive days. Contractors were not included in bonus schemes (except on two mines), but direct employees are penalised if a contractor has an incident. Workers, managers, and contractors believe reporting LTIs would have negative consequences for contractors and their employees. Contractors are left out of consultative processes.
Bahn (2012)	Australia	Case study (one mine) – move to direct employment 2011. Phone interviews with mine undermanager and a safety consultant. Work-related injury statistics were collected and tracked from July 2010 to September 2011.	Noted improved supervision and hazard reporting associated with the move towards direct employment. Using a mix of contractors and direct employees introduces complexity associated with managing multiple safety regimes. The author claimed a downward trend in injury statistics, including near-misses and first aid injuries (but 15 months of data is insufficient to support this claim).
Bahn and Rainnie (2013)	Australia	Case study – secondary analysis of interviews with owner-operator personnel, representatives of contractors, and managers of a labour hire contractor supplying labour and equipment to five mines across Australia.	Identified both extensive outsourcing and work being taken back in-house. There are no longer clear negative consequences for OHSM associated with networked organisation. However, mining companies identify (1) failure of the contracting company to take responsibility for supervising their employees and (2) ambiguous OHS regulatory responsibilities.
Quinlan (2014)	Developed economies	Case studies – analysis of major mining disasters resulting in the Ten Pathways model of incident causation.	Contracting arrangements driven by a desire to cut costs introduce disorganisation into OHSMS. • Outsourcing maintenance and engineering design flaws; • OHSMS flaws – complex multi-tier subcontracting undermines effective training, hazard and incident reporting, consultation, and feedback; • Regulatory failure (challenges associated with complex multi-employer work sites); • Undermines union representation of workers (communication and trust between employees of different companies).

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Table 6. (*Continued*)

References	Country	Sample and method	Health and safety outcomes or adverse effect of contracting on OHSM
Yilmaz (2015)	Turkey	Quantitative – standardised occupational accidents rates and changes of insured workers of the private and public sectors were investigated in the coal mining industry.	Most of the coal mines are operated by lessee private sector enterprises, but coal is produced without adequate safety measures. 11 of 12 great accidents since 1992 occurred in private sector mines (i.e., not TTK mines), and 937 workers died due to explosions and fires. The increased occupational accident rate is due to the increased private sector employment.
Erkan, Ertan, Yeo, and Comfort (2016)	Turkey	Case study – Sociotechnical systems method to analyse cause of the Soma-Ezed mine explosion.	Subcontractors are paid on excavation distance, not coal produced. This incentivises excavation of large areas, leaving coal exposed to oxygen. increasing the risk for spontaneous combustion.
Walter (2017)	Patagonia (petroleum)	Case study – one multinational and one national company operating off-shore oil platforms. Questionnaire and 53 focus groups at 8 different locations with 215 interviewees (60% of respondents were employees of contractors).	The impact of an OSHAS 18001 compliant SMS on OHSM. • Multinational platform – OSHAS 18001 improved OHSMS practices, e.g., use of work permits and risk assessments. Emerging hybrid forms of subcontracting delivering better coordination, strict supervision, and more worker participation contributed to better safety management. • National platform – pressure to reduce costs resulted in continued use of contractors for high-risk work such as the well-head.
Nygren et al (2017)	International	Literature review of peer-reviewed literature up until early 2015.	Identified three themes from the literature: • Contract work characteristics such as economic pressure, job insecurity, task demands, and low autonomy. • Structural/organisational factors such as fragmentation and ambiguity around roles and responsibilities, and workers at the bottom of the subcontracting chain have limited access to consultation and limited ability to influence decisions. • Heterogeneous nature of multi-employer work sites creates difficulty in establishing safety norms.
Nygren (2018) Thesis	International	Cross-sectional – multi-method approach including Swedish Work Environment Authority documents, insider accounts via interview from one SWEA's inspector, and key informants from a mining company outsourcing work.	Difficult to draw conclusions about the adverse effect of outsourcing on OHS outcomes due to inconsistency in OHS measures used. Communication and cooperation between the social actors involved is difficult. Difficult for mining companies to implement their safety functions and not infringe the contractor's employment responsibilities. Different actors operate in different jurisdictions in the regulatory space. Regulatory change may blur the previously established boundaries of jurisdiction and undermine the perception of the contractor's capability.

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Table 6. (*Continued*)

References	Country	Sample and method	Health and safety outcomes or adverse effect of contracting on OHSM
Valluru, Dekker, and Rae (2017) Thesis article	Australia	Cross-sectional – Literature review and cross industry focus groups.	Organisations enter subcontracting arrangements as they offer productivity advantages. Contracting is not adequately addressed by regulations or safety management systems.
Valluru et al (2020) Thesis article	Australia	Cross-sectional – thematic analysis of six single fatality investigation reports sourced from the mining regulator. Small sample – six fatal incidents between 2004 and 2014.	• Safety management systems do not cope with the variability introduced by the subcontracting system. • Expertise in work does not translate to expertise in safety. • Communication does not flow to the subcontractor from the layers above. • Safety activities are not viewed as core a core activity by subcontractors.
Valluru, Dekker, Rae, and Chamberlain (2022) Thesis	Australia	Ethnographic study – 20 hrs of field observation of employees of three subcontractors at one mine.	Employee safety voice is influenced by their standing (i.e., informal hierarchical position on the worksite). Workers with lower standing are less likely to stop work if unsafe and report injuries to their manager. Contractors perform 'dirtier' work, have lower job autonomy, and invoke paternalism from the principal contractor and principal contractor workmates. Contractor's supervisors have more control, e.g., may ask them to undertake work in an unsafe manner. Subcontractors feel they do not have the power to refuse.
McDermott and Hayes (2018)	Australia	Case study – 36 face-to-face interviews with managers and supervisors of principal and civil contractor partners.	Responsibility for meeting compliance costs was distributed unequally, with the majority borne by contractors and exacerbated by competitive tendering processes.
Knights and Scanlan (2019)	Australia	Quantitative – relationship between commodity price cycles and fatal mining incidents (statistical analysis in excel spreadsheet). Queensland mine fatalities sourced from Qld mining regulator; thermal coal price 1985–2016 sourced from IndexMundi; labour force data from Australian Bureau of Statistics, 2018.	Coal prices below AUD 55/tonne [appeared to be associated] with increased multiple fatality incidents. The author concluded that market downturn leads to downsizing, which in turn may lead to increased use of contractors. Authors cited an unpublished review of Queensland mining incidents by a mining inspector that found 6 of the 7 recent fatalities were contractors and 9 out of 10 of high-potential incidents involved contractors.

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Table 6. (*Continued*)

References	Country	Sample and method	Health and safety outcomes or adverse effect of contracting on OHSM
Milch and Laumann (2019)	Norway (offshore oil)	Cross-sectional – analysis of 22 incident regulatory incident investigation reports.	Underlying systemic deficiencies at the interorganisational level that obscure operational processes and reduce the effectiveness of existing safety barriers. • Ambiguities in roles and responsibilities between personnel from different companies; • Inadequate processes to ensure sufficient competence across interfaces; • Inadequate quality control routines across organisational interfaces and communication breakdowns between companies.
Jackson (2021) Thesis	Australia	Cross-sectional – analysis of 51 published regulatory investigation reports on serious incidents. Review of company annual reports and government economic reports.	28 of 51 incidents, including eight fatalities, involved subcontracting or labour hire arrangements. Hours worked by contractors, estimated by NSW Resources Regulator as 46.5% in 2018–19. • Embedded service contractors and production labour – job demands and equipment/resourcing issues contributed to work pressures. Supervisors failed to identify non-compliant practices evolved to satisfy work demands. • Maintenance and testing services – relied on trade competencies and people-based controls such as energy isolation, dissipation, and testing for dead rather than engineering controls. • Agency engineers, technicians, or supplementary labour – unclear roles, responsibilities, and poor communication between direct employees and contract personnel; failed risk assessments; production, or project pressures. • Engineering project contracts – poor communication across organisational interfaces, including lack of opportunity for subcontractors to raise concerns; inadequate risk assessment or geological assessment and risk control or unexpected geological conditions creating additional risks; regulatory failure relating to project approvals/exemptions and equipment design/item registration.
Hashemian and Triantis (2023)	International	Systematic literature review on production pressure (also referred to as work/ workload/ time/schedule/economic/commercial/ performance/ efficiency pressure).	Subcontracting was identified as a production-focused but risky managerial strategy contributing to production or work pressure. Only four articles on production pressure in mining/oil and gas industries.

Table 7. The global supply chain and artisanal small-scale (gold) mining (ASM/ASGM)

References	Country	Method & sample	Adverse effect of precarious employment on OHSM
Le Coze (2023)	International	Discursive The "global turn" in research is discussed, using sociology and history as examples.	Complex global value chains made up of joint ventures, outsourcing, and subcontracting (e.g., "networks of networks" properties, Dicken 2007). The increase in flows in global value chains leads to "network failure accidents" (complementing the "component failure accidents" of Perrow, see Le Coze 2020).
Alsamawi et al (2017)	International	Quantitative Global supply chains – occupational safety and health footprints (OSHF) calculated using multi-regional input-output (MRIO) analysis.	Accidents throughout global supply chains are hidden. In 2010, there were 12 fatal and 4.8 thousand non-fatal incidents, 27 thousand days lost, and two million US$ lost in wages per 100 thousand workers in supply chains worldwide. • Consumer-developed countries outsource negative OHS effects to supplier developing countries.
Harpur (2009)	Australia	Thesis Doctrinal research methodology to answer pre-determined questions about worker rights, corporate social responsibility, and regulatory options.	Australia fails in its human rights obligation to regulate health and safety in supply chains from which it benefits.
Sánchez-Vázquez et al (2016)	Ecuador	Cross-sectional – semi-structured interviews in 2012–2013 and review of archival documents.	Granting mining concessions to foreign companies has created conflict between artisanal miners and big mining companies (Warnaars and Bebbington 2016; Latorre 2012). • Illegal mining is a source of income, but illegal miners lack financial resources to invest in safety. • Those who discovered the gold fields in the area do not even have the necessary permits to work the area legally, nor are provided with the guidance to operate safely.
Prentice and Trueba (2018)	Bolivia (miners) Trinidad (garment workers)	Ethnographic – comparison of two ethnographies independently undertaken to understand how they both reflect a single theme.	In Potosi, mining is associated with high rates of occupational injuries, disease, and death (Trueba 2014). Over 200 miners died from work-related accidents and diseases during 2009 and almost 3,000 sought primary health care after work-related injuries. • Cooperatives, comprised of ethnically heterogeneous, self-organised work teams, rent mines for a yearly fee and a monthly percentage of the production. • The boundaries between formal and informal employment are hard to distinguish.

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Table 7. (*Continued*)

References	Country	Method & sample	Adverse effect of precarious employment on OHSM
Martinez et al (2021)	Peru	Case study of one formalised mining operation.	Peru has formalised over 9,600 artisanal miners. Formalisation of ASGM activities has become a key strategy for governments to better govern and regulate the sector, but formalisation has mixed results. • Formal operations have better health and safety practices and labour conditions. • Informal miners have difficulty obtaining technical support and accessing capital. • ASG miners feel more pursued and scrutinised than when they operated informally.
Saldaña-Villanueva et al (2022)	Mexico (mercury)	Prospective cross-sectional observational study. Blood and urine analysis Soil and water analysis	Chronic exposure to different environmental pollutants can have a direct impact on the risk of health deterioration in precarious employment. Labour and health inequality due to lack of • labour regulation; • protective equipment; and • income below the minimum wage and lack of social security.
Elgstrand et al (2017)	South Africa	Discussion	Most occupational hazards in informal mining are a consequence of poor physical conditions, such as ground failure and shaft collapses. Machinery accidents, poor lighting and ventilation, electrocution, and explosive misuse. Accidents are under-reported in ASM. The ILO estimates that non-fatal accidents are six to seven times greater than in formal, large-scale operations.
Calys-Tagoe et al (2017)	Ghana West Africa	Cross-sectional – Interviews about occupational injury experiences over the preceding 10 years. 404 participants from 5 licensed and 4 unlicensed mine sites were recruited in 2014.	Miners working in unlicensed gold mines experienced more injury episodes compared to miners on licensed mines – 26% vs. 8%. The injury rate for those working in unlicensed mines was 5.9 per 100 person years (59 injuries in 995 person years) versus 5.0 per 100 person years (62 injuries in 1250 person-years) in the licensed mines.
Mensah, Siabi, Donkor, and Kurantin (2022)	Ghana West Africa	Cross-sectional – safety climate (NOSACQ-50/Management safety priority scale). 100 respondents from random sampling and purposive sampling of 10 government agencies. Secondary data sources such as journals, periodicals, and the internet were used.	In 2011, 300 deaths were recorded spanning across artisanal and small-scale mining, respectively (statistics from the Ghana Chamber of Mines). Identified production priority due to managers pressuring workers not to comply with regulations and cut corners.

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Table 7. (*Continued*)

References	Country	Method & sample	Adverse effect of precarious employment on OHSM
Zvarivadza and Nhleko (2018)	South Africa	Review	The fatality rate in ASM is up to 90 times that of large scale mines in industrialised countries (Zungu 2016) Mine Health and Safety Council, South Africa). In Ghana between 2009 and 2016, at least 86 fatalities in small scale mines of Ghana due to ground failures (Bansah et al 2016).
Ajith and Ghosh (2019)	Kenya East Africa	Cross-sectional – 33 severely injured miners selected by purposive sampling. Semi-structured interview and survey comprised of questions about economic, social, and lifestyle challenges post-sustaining the injury.	Mine owners and miners believe production supersedes safety. Hazards are ignored to achieve the production target. • If the accident occurs, neither leadership nor miners are held accountable. • Accidents and injuries and post-injury impacts are rarely documented except in the catastrophic events that have been reported by the media.
Kılıç et al (2020)	Turkey	Review	Small- and middle-sized illegal mines/suppliers operate between legality and illegality, often extracting coal from sites subcontracted to legal companies by TTK. Micro-illegal mines are fully illegal and are worked by groups of friends or relatives extracting coal from their private land, sharing the risks and earnings.
Sovacool (2021).	Democratic Republic of Congo	Cross-sectional – 23 semi-structured interviews with ASM miners, traders, and community members. Observations during 17 site visits to artisanal mines, processing centres, and trading depots.	The low-carbon economy supply chain has inadvertently contributed to dispossession and modern slavery. Amnesty International warned of exploitation and child labour, but government regulation has not adequately addressed these issues. • Formalisation resulted in a scarcity of permits and exorbitant costs. • Artisanal miners remain outside the legal economy as they lack the financial resources, skills, and literacy to navigate the registration process.
Calvão et al (2021)	Democratic Republic of Congo (cobalt)	Ethnographic study involving three case studies on ASM to examine corporate-led formalisation projects. Survey conducted among 81 artisanal miners and interviews with relevant stakeholders in the cobalt economy.	Reliance on wageless, artisanal workers in large-scale industrial operations leads to unexpected collaborations at the edges of capitalist extraction. The flexible recruitment of artisanal workers by mining companies represents an emergent trend of corporate outsourcing of responsibility.

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Table 7. (*Continued*)

References	Country	Method & sample	Adverse effect of precarious employment on OHSM
			Compromises artisanal workers access to the market and undermining economic security. Responsible sourcing schemes in mixed mines further tilt the burden of price fluctuations, job insecurity, and economic precarity onto miners themselves.
Manchisi, R. (2019).	Zambia	Thesis Qualitive – 50 semi-structured interviews. Analysis – content coded in NVivo based on a predetermined sustainability framework.	Informal SMEs (small to medium enterprises or focal mining firms) are the majority of SMEs in Zambia. The law requires mining firms to trade with only formal businesses, but informal SMEs actively participate in the mining supply chain by trading with formal SMEs. The role of first-tier suppliers (formal) was a bridge between the focal firms and sub-suppliers (including informal miners). Supplier SMEs are required to have an H&S policy. They predominantly work under the focal firm policy. If they have their own policy, the purpose is to win contracts not H&S.
Singo et al (2022)	Zimbabwe	A cross-sectional survey – 401 ASG miners. Statistical analysis using descriptive statistics and regression analysis.	The prevalence of accidents and injuries was 35.0% and 25.7%, respectively. Accidents associated with experiencing injuries included mine collapses and underground trappings. The major injury risk factors were digging, blasting, being male, being 18–35 years old, crushing, and the underground transportation of workers and materials. Injuries were reported highest among the miners working 16 to 24 h per day.
Nayak (2022).	India	Qualitative – 200 "ethnographic" interviews with coal mining workers, supervisors, and managers; union leaders; and local state administrators conducted between 2018 and 2020 in the Talcher coalfields of Odisha.	The labouring lives of migrant workers from marginalised communities have been "invisiblised" as a 'shadow economy' of the coal extraction sector under the state-owned company in postcolonial India. The subcontracting system and 'labour supply' through local contractors since the 1990s have deepened informality and exploitation of migrant workers in state-owned coal mines.
Robles et al (2022)	Philippines	Cross-sectional study using questionnaires and in-depth interviews, observations, and informal conversations.	ASGM produces a 5th of world gold, but 70%–80% operate outside government regulation. The evidence for better health and safety outcomes due to formalisation is inconclusive as labour issues are not addressed. Workers in informal mines are exposed to mercury, while at formal mines processing occurs at a different location.

this vulnerable group of workers and advanced the interests of large multi-national mining companies (Calvão et al 2021; Martinez et al 2021; Nayak 2022; Robles et al 2022; Sánchez-Vázquez et al 2016; Sovacool 2021).

The literature paints a consistent picture of multi-tier subcontracting, resulting in ASMs working at the bottom tier of the chain and blurring the boundaries between legal and illegal operations (Kılıç et al 2020; Manchisi 2019). Alsamawi et al (2017) calculated the OHS footprints within the global supply chain and noted developed consumer countries outsource adverse OHS outcomes to developing supplier countries. Sovacool (2021) observed that the low-carbon economy supply chain has inadvertently contributed to dispossession and modern slavery. The doctoral thesis on corporate social responsibility and regulatory options by Harpur (2009) argued that Australia has failed in its obligation to regulate OHS in supply chains from which it benefits.

Authors report higher injury measures amongst ASMs (Calys-Tagoe et al 2017; Elgstrand et al 2017; Prentice and Trueba 2018; Singo et al 2022; Zvarivadza and Nhleko 2018) and lack of resources to negotiate formalisation processes and invest in OHS equipment and practices (Martinez et al 2021; Saldaña-Villanueva et al 2022; Sánchez-Vázquez et al 2016; Sovacool 2021).

Discussion

In the literature review, we examined the evidence linking poorer OHS outcomes with contracting or subcontracting compared to directly employing labour and the extent to which risk factors identified in connection with the use of contract labour in mining align with factors identified in the PDR and Ten Pathways models. Overall, the findings are very consistent. With very few exceptions, the studies point to a link between contracting or subcontracting and poorer OHS indices using a variety of measures, and this result is consistent with earlier and more generic reviews of research on the OHS effects of contract labour (Quinlan and Bohle 2008). This is a significant finding with important policy implications. At the same time, if attention focuses on quantitative studies, some problems and complexities need to be acknowledged.

The results also present a complex picture hampered by data quality issues. Firstly, a key issue raised was the lack of accurate exposure data for contractors (Blank et al 1995; Buessing 2014; Charles et al 2022). In addition, authors from the USA noted under-reporting by smaller operators and under-reporting of non-fatal incidents by employers in the mining industry (Friedman et al 2019). It was also noted that mine operators do not accurately report the number of contractors working on their site (Buessing 2014). When accurate exposure data were available, analysis showed contracting was associated with higher injury measures (Blank et al 1995; Pappas and Mark 2011). Focusing on the sector (i.e., coal, metals, or construction materials), owner-operated coal mines were found to have more injuries than all other categories of mine operation, but they had fewer fatalities (Buessing and Boden 2016; Karra 2005; Pappas and Mark 2011). This suggests measures that are less prone to manipulation provide a more realistic reflection of OHS performance.

Second, contracting and subcontracting is not all the same. Contractors provide a range of services in different work environments (Buessing 2014; Nygren et al 2017) and under a variety of contracting arrangements (Quinlan 2024). Studies found a greater likelihood of adverse outcomes associated with 'riskier' work and mines with poorer OHSM, measured by inspector citations for contractor violations (Buessing 2014). Another study found that contractors accounted for a greater proportion of long working hours injuries (Friedman et al 2019). In Australia, Shaw et al (2007) found that contractors across the whole industry worked longer hours than direct employees and that this was more so in the metalliferous

sector, where contractors worked 65.85 hours compared with direct employees who worked 52.40. Blank et al (1995) argued that the true state of contractor health and safety in the mining industry is hidden by a lack of accurate exposure data for contract workers. This may account for the relatively small number of quantitative studies over the last 25 years and highlights the need for improved data collection by mining regulators and agreed terminology consistently applied by researchers.

Third, comparing contractor-operated with mine-owner-operated mines, while useful, masks the fact that in many instances, contractors will be working in some capacity at owner-operated mines, including areas like maintenance where Australian mine fatality data discussed below indicates are over-represented in fatalities. The presence of contractors and direct employees on the same site also has the potential to create situations where failures in contractor OHS impact other workers.

In sum, there is a need for more differentiated research, which may be challenging given available statistics, and we return to this in our policy suggestions. It should also be noted that almost all of the flaws just identified are liable to lead to an understatement of differences in OHS between contractors and employees. The methodological difficulties are, therefore, not a basis for querying the association between contracting and poorer OHS indices that the vast majority of studies have found. More differentiated research may actually indicate comparative risks are greater as well as better identifying the areas where policy interventions should focus.

As we noted in the introduction, work practices are continually evolving, and this is often an adaptation to political and economic demands. The carbon reduction imperative has seen major mining companies move away from coal mining in the developed economies towards other mineral and metal mining. The literature search returned many research and review articles describing an alarming trend towards subcontracting and other precarious work arrangements, including exploitation of vulnerable workers at the bottom of metal and mineral supply chains. Illegal mine workers are co-opted into providing labour for larger legal mining companies, and government legislation formalising ASM has created conflict between artisanal miners and large corporate mining companies (Calvão et al 2021; Manchisi 2019; Sánchez-Vázquez et al 2016). With the move away from high-carbon emitting energy sources, demand for electric-batteries has tripled the consumption of cobalt (Calvão et al 2021). The Democratic Republic of Congo is the largest producer of cobalt, and Calvão et al (2021) reported that the government is pushing the formalisation of artisanal and small-scale mining by multi-nationals under the banner of responsible sourcing. Furthermore, Calvão et al (2021) argue that '*the flexible recruitment of artisanal workers by mining companies represents an emergent trend of corporate outsourcing of responsibility*'. Although formalisation is intended to improve safety conditions in small-scale mining, Calvão et al (2021) argue that it provides the foundation to exploit wageless working conditions. As citizens of developed consumer economies and actors in the global economy, we should bear some responsibility for managing the risks we outsource to developing supplier economies (Harpur 2009; Sovacool 2021). There is a small body of literature examining the role of corporate social responsibility and sustainable practices as a means of preventing exploitation of vulnerable workers. See, for example, Bester (2022). Further articles on this topic were excluded as, on the whole, these frameworks failed to identify subcontracting as a key sustainability practice.

Qualitative research in both developed and developing economies utilising contractors and subcontractors participating in multi-tier supply chains identifies similar causes of adverse health and safety outcomes associated with these labour arrangements. Research identifies causes consistent with those identified by Ten Pathways and the underlying conditions described by PDR. Researchers examining the impact of informal/illegal mining on OHS consistently identify economic pressures, failure of government policy and OHS regulations, and lack of OHS knowledge, resources, and support to implement OHS

practices (Bester 2022; Küçük and Ilgaz 2015; Saldaña-Villanueva et al 2022). PDR is a valuable model for understanding causes of adverse OHS outcomes in illegal/informal mining in developing economies.

Contractor safety: Some illustrative incidents

Beyond reviewing research on contractors and OHS, it is also worth examining what investigations into serious incidents reveal about causal pathways. Within the context of this paper, it is only possible to briefly examine four incidents, three in Queensland and one in NSW. These are however representative of many contractor-related incidents examined by Jackson (2021) and fit within a growing debate over contractor safety, especially in Western Australia and Queensland, where analysis of mine fatalities (and serious mine accidents in the latter, i.e., those requiring hospital admission), indicate contractors are over-represented and most typically associated with repair/maintenance activities (Brady 2019; Department of Mines and Petroleum 2014). As an aside, it is also worth noting that the observations of Queensland Industry Safety and Health Representatives (ISHR), who are full-time statutory OHS representatives employed by the Mine Employees Union) drawn from these and other incidents matched some key findings of published research and the PDR model. Notably, the ISHRs believed contractors were at greater risk because their insecurity/fear of dismissal without reason reduced willingness to raise safety issues and acted as an incentive not to 'rock the boat' in the hope of securing a better-paid, permanent job. ISHRs also saw contractors as having less education/training due to cost pressures and generally overseen by less experienced supervisors. The ISHR response to these concerns has been to monitor high potential incidents (HPIs), try to ensure mine management focuses on contractor issues, inspect contract areas of mines and workshops (where a significant number of contractor fatalities have occurred), ensure site safety and health representative (SSHR) identity and contact details are displayed in contract start-up areas, audit high-risk activities (hot work, confined spaces, and working from height), participate in tripartite incident data analysis, provide information on contractors in SSHR training workshops, and promote academic research.[2]

Table 8 provides a summary of the four incidents drawn from the official investigations by the regulator, or in the case of Grosvenor, an Independent Board of Inquiry (BOI) into the incident (Queensland Coal Mining Board of Inquiry 2021).

At the Mount Arthur open cut mine in 2017, a tyre replacement contract worker was severely burnt while refuelling a tyre handler vehicle at the heavy vehicle refuelling station using a free flow adapter nozzle. The hose detached and fuel spread over a hot engine, which ignited. The investigation found that heavy vehicle refuelling equipment was not compatible with tyre handler vehicle's filling neck. To overcome this problem contract workers used an adapter that bypassed the automatic cut-off safety feature. Forces acting upon the adapter caused it to eject from the filling neck, and diesel fuel entered the engine bay and ignited on the hot engine surface. The tyre handler vehicles used the heavy vehicle refuelling station because of problems accessing fuel from the field-based refuelling cart. Refuelling had not been identified as a risk and therefore no risk assessment had been undertaken (pathway 3). Mine management was not only unaware that contractors were using the heavy-vehicle refuelling station and the non-approved adaptor, but also had no knowledge of informal communication between service groups directing contract tyre-handler operators to the heavy-vehicle refuelling station due to work demands/delays accessing the approved refuelling cart (pathways 4 and 6). Audits failed to identify use of the non-approved adaptor (pathway 5), and contractor management failed to provide contract workers safe access to refuelling (pathway 4). In the lead-up to the incident, the tyre handler vehicle required refuelling to respond to an

Table 8. Sub/contractor incidents and Ten Pathways

Incident	Mount Arthur mine NSW 2017 tyre replacement contractor seriously burned	Newlands coal prep plant (Qld) 30 August 2016 Contractor killed by falling deck plate	Goonyella mine (Qld) 5 August 2017 contractor employee killed by plate spring up during maintenance on bucket	Grosvenor mine Qld May 2020 methane explosion, five seriously burned
Pathway 1	No system to prevent access to the heavy vehicle refuelling station, and subcontractors were not trained in its safe use.	Inadequate task planning/optimal engineering approach	Original manufacturer not consulted re maintenance on buckets and indentations in wear plates major reason for stored up tension	Methane drainage prior to the incident inadequately monitored/ managed.
Pathway 2				Pattern of gas exceedances for some time prior
Pathway 3	Lack of task-specific risk assessment and refuelling not considered high-risk by the service contractor	Inadequate planning and risk assessment of task. Investigation found several risks in the task were foreseeable	No formal risk assessment undertaken regarding modifications to bucket	BOI found number of failures to risk assess gas exceedances as conditions changed
Pathway 4	Lack of clear communication to refuellers about their responsibility to refuel tyre handlers; Contractor management – failed to provide subcontractor safe access to refuelling. Work demands and disorganisation contributed to subcontractors using a non-approved adaptor.	Inadequate contractor management, poor work tasking planning, inadequate safe work statement, and supervision deficiencies	Contrary to OHSMS, contract worker didn't have relevant 'hot work' training and trade certificates and considerable confusion regarding supervision of task. Also, clear deficiencies in contractor management	OHSM regime weakened by extensive use of labour hire, especially report back mechanism
Pathway 5	Audits failed to identify the non-approved adaptor	Glencore/UGL contract extension clause not exercised in 2016 so had expired and further several deficiencies in SOP etc. long standing so should have been picked up by an effective auditing regime	Auditing failed to pick lack of planning in maintenance, risk assessment procedures, and supervision, several of which were longstanding deficiencies	BOI identified the number of auditing failures and recommended improvements
Pathway 6	Work demand pressure and urgent request lead up to incident			Mining operations were repeatedly conducted in a manner where gas emissions generated by the rate of production exceeded mine's gas drainage system capacity (BOI)

(*Continued*)

Table 8. (*Continued*)

Incident	Mount Arthur mine NSW 2017 tyre replacement contractor seriously burned	Newlands coal prep plant (Qld) 30 August 2016 Contractor killed by falling deck plate	Goonyella mine (Qld) 5 August 2017 contractor employee killed by plate spring up during maintenance on bucket	Grosvenor mine Qld May 2020 methane explosion, five seriously burned
Pathway 7				Inspection regime tended to accept management reassurances/some disorganisation (visits/record coordination)
Pathway 8	Prior concerns had been expressed			
Pathway 9		Evidence of poor contractor-worker management communication		Labour hire workforce afraid to report issues and union input marginalised (e.g., electronic exchange of inspection reports). Some issues raised were ignored (note only one labour hire employee gave evidence to BOI).
Pathway 10				Rescue worked but serendipitous as anesthetist vising town on day able to stabilise miners so could be airlifted to hospital with burns unit

urgent service request (pathway 6). Concerns expressed prior to the incident (pathway 8) were also present. Following the incident, the contractor company provided a dedicated refuelling cart for tyre handler vehicles, and a mining company audit identified non-approved adaptors in use at other mines – in short, this was a systemic, not an isolated, problem (Jackson 2023).

In the second incident on 30 August 2016, a contract worker was killed by a falling deck plate at the Newlands coal preparation plant in Queensland (Department of Natural Resources and Mines 2017). The investigation identified inadequate task planning and suboptimal engineering approach (pathway 1), inadequate planning and risk assessment of the task and the investigation found several risks in the task were foreseeable (pathway 3); inadequate contractor management, poor work task planning, inadequate safe work method statement, and supervision deficiencies (pathway 4). The Glencore/UGL contract extension clause was not exercised in 2016 so had expired, and there were longstanding deficiencies, including the safe operating procedures (SOP) that should have been picked up by an effective auditing regime (pathway 5). There was also evidence of poor contractor-worker-management communication (pathway 9). In the third incident, an Independent Mining Services employee was killed at the Goonyella mine in Queensland on 5 August 2017 when he was hit by a plate spring up during maintenance on a bucket (Department of Natural Resources Mines and Energy 2019). The investigation found the original manufacturer was not consulted regarding modifications made to wear plates on the buckets, and indentations in the wear plates were a major reason for stored-up tension (pathway 1). There had been no formal risk assessment undertaken regarding modifications to bucket (pathway 2). Contrary to the OHSMS, the contract worker lacked relevant 'hot work' training and trade certificates; considerable confusion regarding supervision of tasks existed; and there were also clear deficiencies in contractor management (pathway 4). Auditing failed to identify lack of planning in maintenance and inadequate risk assessment procedures and supervision, several of which were longstanding deficiencies (pathway 5).

Finally, it is worth considering a serious near miss or HPI at the Grosvenor coalmine in Queensland when a methane explosion seriously burned five workers (Queensland Coal Mining Board of Inquiry 2021). But for several serendipitous factors, the result could have been catastrophic. Most notably, an unplanned build-up of stone dust near the explosion zone prevented the methane explosion transitioning to a coal-dust explosion, endangering both the five burned and others underground, and the presence of an anesthetist visiting the town that day doing COVID training who was able to stabilise the burned miners so they could be transported to a burns unit. The Board of Inquiry identified several failures, including inadequate methane drainage/monitoring (pathway 1), mine had experienced a number of gas exceedances prior to the incident (pathway 2), there were inadequacies in risk assessment (pathway 3), the use of labour hire weakened problem reporting (pathway 4), there were a number of auditing failures (pathway 5), and production was knowingly exceeding methane drainage capacity (pathway 6). The Board of Inquiry also identified deficiencies in inspection/enforcement by the regulator (pathway 7) and limited communication between management and the predominantly labour-hire workforce (pathway 9).

Taken as a whole, Table 8 shows examination of the investigation reports indicates that four failures were present in the Goonyella and Newlands incidents, six at Mount Arthur and eight at Grosvenor. It is important to note that these investigations were not guided or informed by Ten Pathways and that it is possible that, except for the more thorough Grosvenor investigation, other pathways may have been present. But even ignoring this, investigation findings highlight the breakdown of management safety systems where contractors are present and afford examples of the disorganisation that is central to the PDR model. This was also identified in contractor safety research discussed above. In two

incidents, the economic/production pressures dimension of PDR, or pathway 6 in Ten Pathways, was also found, and Grosvenor afforded evidence of regulatory failure. In sum, examination of these incidents is consistent with and reinforces the findings of research reviewed earlier.

Policy implications

As noted earlier, the OHS challenges posed by contract labour have been recognised for some time, and a number of general responses have been suggested to control or mitigate these effects (Quinlan 2024; Underhill and Quinlan 2011). From an organisational perspective, suggested remedies include making contracting decisions in a more strategic and OHS-informed manner so that some activities may be contracted out while others will not because the risks cannot be adequately controlled. This approach accepts that cost-cutting alone is not a good driver for contracting decisions, especially when the additional costs of risk assessment and controls are factored into costs. For example, based on a review of the Soma mine explosion investigation findings in Turkey, Demiral and Ertürk 2013 recommended subcontracting should not be permitted for core high-risk activities in underground coal mines. Consistent with this may also be a recognition that significant disparities in pay, rights, and entitlements between direct-hire and contractors/labour hire are likely to create tensions and may prove a recipe for poor morale, disorganisation, corner-cutting, and reporting/surveillance problems that will undermine OHS. This disparity was also identified as a significant concern for the social security of ASM/ASGMs in developing economies (Calvão et al 2021; Ehrlich et al 2017; Nayak 2022; Saldaña-Villanueva et al 2022; Sovacool 2021).

Requirements for a safer approach to contracting include comprehensive hazard identification and risk assessment, extensive SOPs, limited use of Job Safety Analysis, rigorous monitoring and auditing, a preference for using specialist contractors, and developing long-term relationships, as well as robust feedback loops, including Health and Safety Representatives and unions, to ensure problems are reported. More general research on contracting/labour hire has identified evidence of these practices (Underhill and Quinlan 2011), but they tend to be atypical, and this also appears to be the case in mining. The studies and cases cited above point to repeated shortcomings in meeting these goals. Some contract mining companies adopt rigorous standards, better pay and conditions (inducing a more stable workforce), but they must still compete against others more driven to cut costs. As the qualitative research described above suggests, cost-cutting is repeatedly seen as the most powerful driver of contracting, with OHS an afterthought to be addressed after this decision is made. On occasion, bodies (like Mining & Resources Contractors' Safety Training Association (MARCSTA)) have been formed to try and raise overall standards of contractor safety, but while valuable, such voluntary efforts have not lasted. From a different perspective, in the developing economies, authors consistently noted that government policies to formalise illegal mining have in many instances contributed to further insecurity, as these workers lack the resources to buy licences and invest in safety (Bester 2022; Martinez et al 2021; Saldaña-Villanueva et al 2022). In these countries, privatisation has paved the way for multinational mining companies to take control of areas previously mined by local communities and created conflict between artisanal miners and the big mining companies (Sánchez-Vázquez et al 2016).

Historically, regulation has been arguably a more consistent and effective driver of safety in mining and more generally. In this regard, Australian OHS and mine safety legislation has several strengths when it comes to addressing contractors. Unlike the laws of most jurisdictions, state/territory and federal legislation in Australia is not framed primarily in terms of employers, employees, and employment but rather the more

encompassing concepts of work, workers, and persons conducting a business or undertaking (which includes any party affecting OHS, including contractors). Some mining laws also contain specific reference to contractors/labour hire. However, this only partly addresses the issues, and as the investigations we examined demonstrate, enforcement remains inadequate. There is a need for more specific regulatory requirements and targeted enforcement by adequately resourced inspectorates, including investigations always specifying the contract status of those involved and indicate how the mine operator and contractor fulfilled contractor safety management obligations. At a broader level, regulators should require detailed information on the use of contractors, including different types, in mines and quarries (which are also covered by mine-safety laws) and collect statistics based on this to better inform inspection, investigation, and enforcement activities. Researchers in developing economies also identify the need for stronger legislation, supervision, and control of mining when there is an informal mining economy, such as in India, Africa, and South America (Vingård and Elgstrand 2013).

Licensing requirements and even outright bans on certain areas of contracting to limit its use are other possible controls. Though unfashionable in this neoliberal age, policy frameworks should actively encourage, not discourage, unionisation of mining operations, given evidence their presence improves OHS outcomes (Morantz 2013). In this regard, it needs to be noted that the growth of contracting has undermined union presence (along with other often related practices such as FIFO and DIDO), something which mining companies are well aware of, if not an objective of this practice. This has weakened the presence of mine-site health and safety representatives and increased the workload on industry safety and health representatives where these exist (NSW and Queensland). As research has shown (Walters et al 2016; Walters et al 2019), these mechanisms are, where they exist, a critical part of the mine safety regulatory regime. Other areas requiring attention include addressing the greater difficulties of monitoring hazard exposures (like respirable dust) of contract workers and making companies more accountable. Concerns around union representation and health monitoring are echoed by researchers in the developing economies (Kenny and Bezuidenhout 1999; Stewart et al 2020; Vingård and Elgstrand 2013). Contracting OHS has been identified as an omission in corporate annual reports (O'Neill et al 2016), and a source of bias in risk assessment (Hunt and Naweed 2023).

Further, the remedies do not lie solely within the realms of OHS legislation but need to include workers' compensation and more specific industrial relations legislation. In this regard, it is worth noting that the 'closing the loopholes' legislation enacted in Australia contains a 'same work same pay' principle that may ensure labour-hire workers are paid the same as direct-hire employees undertaking the same tasks (Underhill and Quinlan 2024). The Australian mining industry vigorously opposed this measure, simultaneously highlighting the importance of costs as an economic driver in its shift to contracting but also the changes in employment practices that could follow when this principle is implemented.

Conclusions

Research and incident analysis provide persuasive evidence that contracting is associated with poorer OHS outcomes in mines, and the trend to greater contracting is very likely making things worse. Knowledge of the connections between contracting and poor OHS outcomes stretches back decades and is consistent with a large body of evidence from other industries. More research is needed on contractors/labour hire OHS, including mental health and suicide, FIFO, DIDO, hours/fatigue management, and hazardous exposures (noise, dust, and chemicals). Nonetheless, this review indicates contracting exacerbates risk because it increases financial/production/reward pressures on workers

and operations, contributes to more disorganised workplaces (less training/induction, more inexperienced workers, over-complicated communication, and inhibits feedback), and weakens regulatory oversight. This aligns closely to PDR and the Ten Pathways model. Critical to the last point, contracting weakens union presence (often deliberate) and worker representation mechanisms (Walters et al 2016; Walters et al 2019) and as evidence suggests, see for example, Morantz (2013), unionised mines are safer. The combination of contracting with reductions in trade union presence and worker representation is a double whammy, which no amount of 'systems' gloss or misinformed safety reforms like trying to apply the high reliability organisation (HRO) approach to mining in Queensland, will offset (for a critique of applying HRO to mining, see Leveson et al (2009)).

Taken as a whole, the evidence on the OHS effects of contract labour in mining is consistent with that pertaining to other industries. The shift to contracting, notwithstanding evidence pointing to its deleterious OHS effects, provides stark evidence of economic considerations trumping OHS irrespective of frequent references to 'zero harm' and robust OHS management systems by organisations embracing the practice. This observation is equally relevant to rich countries with high-developed regulatory regimes such as Australia and poor countries in Africa and elsewhere often marked by weaker regulatory regimes (often compromised further by corruption) and limited union presence. With regard to the last point, we noted the problematic effects of the shift to post-carbon economy mining developments, including the use of undeclared work and shifting oversight responsibility to mining corporations. This affords another example of economic drivers undermining OHS.

As we noted, there are some measures mining organisations can take to mitigate OHS risks. While not without value, the limitation of a voluntary approach is that those doing this, like some contract mining companies, run the risk of being undercut by operators more concerned with cost considerations. Overall, more effective remedies lie in realms of legislation, especially strengthened industrial relations laws to further extend important reforms in closing the loopholes as well as more rigorous OHS regulation and enforcement by mine inspectorates. We would suggest that the Ten Pathways model provides a guide/template for the latter, especially as the pathways align with existing mine safety laws, especially the OHS management systems requirements to undertake risk assessment, audit systems, and the like. Importantly, the Ten Pathways model (and PDR) includes explicit reference to economic/production pressures compromising safety. This failure point needs to be recognised and addressed to reduce serious injury and health risks in mining.

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Notes

1 Odds ratios may have been preferred by authors due to the lack of contractor hours worked in the USA Mine Safety and Health Administration Mine and employment database.

2 Personal communication and information provided by Steve Watts, Queensland ISHR 9 February 2024.

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Heather Jackson B.ASc(OT) (Sydney), B.EdSt (Newcastle, Australia), PhD (Newcastle, Australia) is an Alumni of the University of Newcastle. She worked for the NSW Mining Regulator in the Industry Assistance Unit. Her PhD examined causes of serious mining incidents using sociotechnical systems and Ten Pathways models. She has published in Safety Science and contributed a book chapter to the Society for Mining, Metallurgy, & Exploration's handbook "Mine Safety & Health: Approaches from the Field".

Michael Quinlan B.Ec (hons) PhD (Sydney) is emeritus professor of industrial relations at the University of New South Wales, Sydney and resides in Launceston, Tasmania. His primary research focus has been occupational health and safety, especially the effects of work organisation and regulation. Michael has undertaken or contributed to a number of government inquiries into OHS, especially in mining and road transport.

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