Rapid Evidence Assessment (REA) of Alternative Indoor Farrowing and Lactation Systems

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1. Background

There are animal welfare concerns about the continued use of permanent crating systems for farrowing and lactating sows. Greater societal attention in recent years has culminated in changes (or proposed changes) to regulation as well as market driven initiatives. Sweden, Switzerland and Norway have had regulations restricting the use of farrowing crates since 1997, Austria[1] and Germany[2] have enacted regulations to phase out permanent crating of sows by 2033 and 2036 respectively and Denmark pledged to have 10% of its herd loose lactating by 2022. In June 2021 the agriculture Committee of the European Parliament debated a European Citizens Initiative, spearheaded by NGOs, to 'End the Cage Age'. This lead to the European Commission tabling a proposal committing that "by the end of 2023, a legislative proposal to phase out, and finally prohibit all cage systems would be in place", possibly as soon as 2027. They stipulated this would follow an appropriate transition period, after a robust scientific impact assessment as part of their evaluation (or 'fitness check') on current animal welfare regulations. Outside of Europe, New Zealand have committed to phasing out farrowing crates by 2025 and in California, USA, Proposition 12 highlights the trend for greater debate amongst various stakeholders about the continued use of confinement systems. In the UK, the Pig Husbandry (Farrowing) Bill was submitted to the House of Commons in April 2021 which focussed on prohibiting the use of farrowing crates.

Assurance schemes in the UK that do not permit the use of farrowing crates in their standards include the Soil Association and RSPCA Assured. Restricted use of farrowing crates is part of various European schemes including Beter Leven (level 2 allowing five days of crating and level 3 allowing three days of crating) and the Danish 3 Hearts scheme (limits crate use from up to four days for 1 Heart, two days for 2 Hearts, and are banned from 3 Hearts standards), with labels in Germany ('Für mehr Tierschutz') preparing to announce 'free farrowing' premiums in the wake of the new German regulations.

Research into alternative farrowing and lactation systems has been active for over 40 years (especially in the UK), but the heightened societal and political interest in this area as outlined above has sparked a great deal more R&D internationally and greater commercial uptake of different systems and practices. The UK pig sector already operates at 40% free farrowing with commercial outdoor production. The indoor pig sector continues to be predominated by the use of conventional farrowing crates. Uptake of alternatives has been limited with constraints including farmer concerns over potential for poorer piglet survival, ease of management and cost. There have been a number of scientific reviews attempting to summarise the evidence base for different systems but there remains a lack of clarity on what works and what will be compliant in the future. This REA cannot predict policy decisions, but it will synthesise the state-of-the-art for different systems and their associated management practices to inform decisions by different stakeholders, including practical information for farmers who may want to change their existing farrowing system.

[1] Verordnung des Bundesministers für Gesundheit, mit der die 1. Tierhaltungsverordnung geändert wird. Bundesgesetzblatt für die Republik Österreich BGBl. II Nr. 61/2012.

[2] https://www.gesetze-im-internet.de/tierschnutztv/BJNR275800001.html

2. Project Aims and Objectives

2.1. Aim

The aim of this project was to produce a report summarising the current state-of-the-art regarding farrowing systems and practices and how they best meet the needs of the piglets, sow and stockperson.

2.2. Objectives

There were several core objectives:

- To provide REAs on farrowing systems that improve total piglet survival and pre-weaning performance, as well as consider other aspects of the piglet's welfare status within the five domains framework.
- To provide REAs on welfare compromises and unintended consequences to the sows of farrowing systems, as well as those that do address aspects of the sow's welfare status within the five domains framework.
- To provide REAs on farrowing systems that consider the well-being of the stockperson.
- To provide REAs on farrowing systems that consider the economic and environmental costs.
- To translate REAs into narrative summaries for each system that can be presented to farmers and through AHDB's EFI.
- To outline existing evidence syntheses and the nature of these syntheses, as well as identify gaps in the evidence-base as a focus for further research priorities and highlight any active research of relevance.
- To provide feedback on AHDB's 'organising framework for evidence' and 'generation and application of evidence standards' working drafts.

2.3. Report structure

The structure of the report is as follows:

- The next section (**section 3**) presents the methodology used for conducting the REAs.
- **Sections 4** present the results of the REA:
    - Scoping exercise – The outcome of the scoping process for identifying the potential farrowing systems and describing them.
- **Section 5** presents the critical review for the REAs:
    - The different aspects of the farrowing systems are discussed including performance (piglet mortality), welfare impacts and opportunities, staff impacts and opportunities, environmental and economic findings with short summaries of main points after each section. Systems that were found to have sufficient evidence are presented as narrative summaries. **Section 6. Appendices** details the EFI methodology (as provided by AHDB).
- **Section 7** presents the narrative summaries for each system
- **Section 8** details our 5 domains results and validity.
- **Section 9** presents the feedback/limitations of the REA.
- **Section 10** provides the References.

3. Methodology

Due to the time constraints of this project, the starting point for gathering of the peer-reviewed evidence-base was to use existing syntheses, including systematic reviews (Glencourse et al. 2019) and descriptive reviews by the authors of the report (Baxter et al. 2011, 2012, 2018). These have been supplemented with the latest research findings, gathered by a systematic search of databases. Information has also been gleaned from relevant final reports from academic and industry research programmes. The grey literature was consulted, particularly for practices relating to day-to-day running of certain farrowing systems. The process for an REA involves a series of steps (summarised in Figure 1).

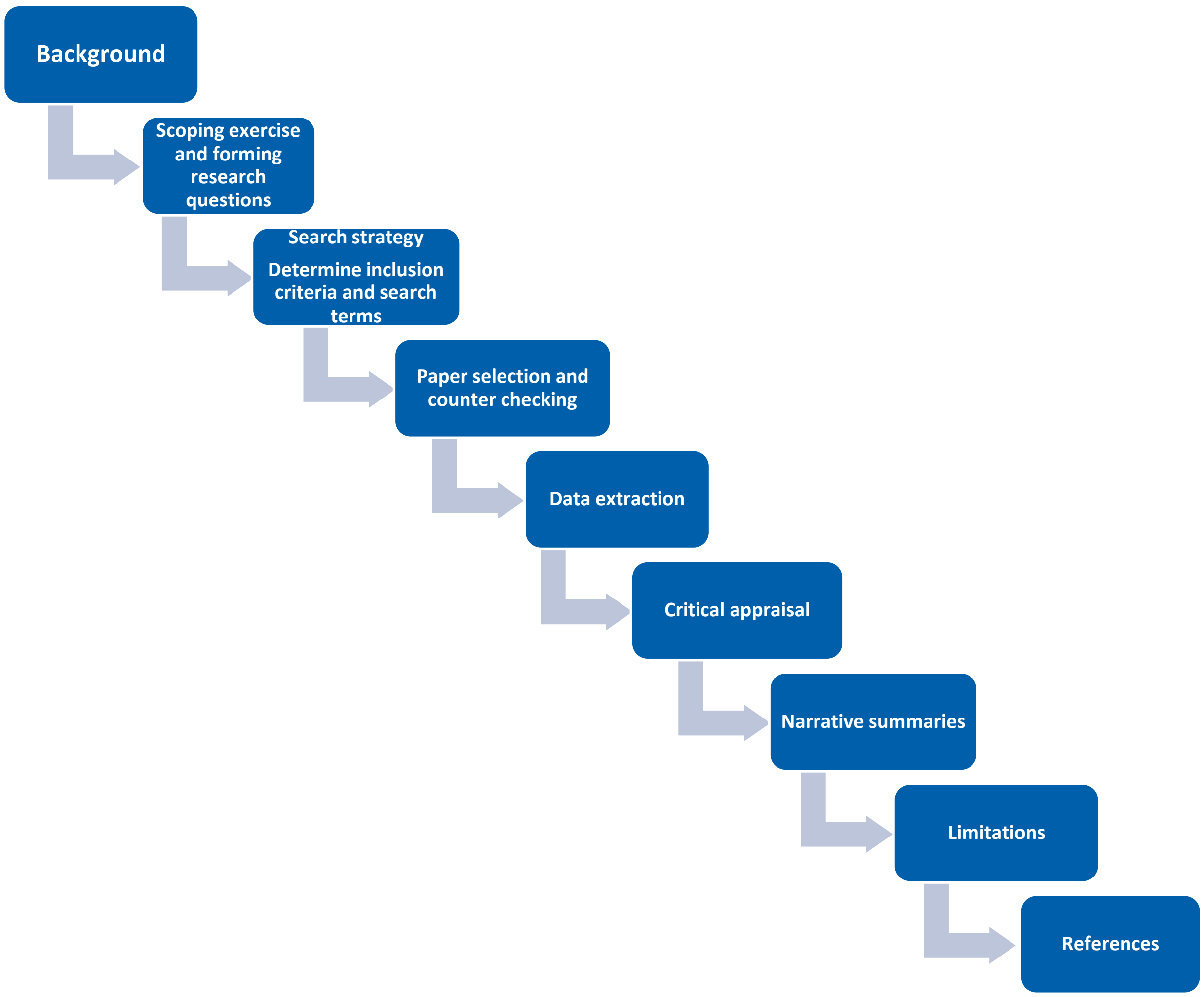


Figure 1. Steps in the REA process

3.1 Identify farrowing systems and practices

A scoping exercise was conducted to identify examples of alternative (to the conventional crate – hereafter referred to as 'alternative') farrowing systems and their associated husbandry practices (hereafter referred to as systems unless otherwise stated). For each of these farrowing systems several research questions were asked to help guide the REA:

- Does the farrowing system deliver good piglet survival?
    - This was determined primarily by looking at studies that had suitable control groups (i.e. the alternative system was compared with the conventional farrowing crate), however we also summarised the performance data from several countries that have operated alternative farrowing systems for some time (Norway, Switzerland and Sweden).
- Does the farrowing system deliver good piglet and sow welfare?
    - Piglet and sow biological needs are summarised and impact of pen design on needs are described. We also generated tables summarising welfare impacts and opportunities from the perspective of the 5 domains as defined by Mellor, 2017.
- Does the farrowing system deliver good stockperson well-being?

- This was determined based on evidence relating to staff safety and ease of management. Evidence was also sought from the social sciences from farmer interviews.

3.2. Defining search terms and databases

Literature searches were not restricted to any specific database or any specific language, though the majority of peer-reviewed papers and book chapters are in English. Searches included combinations of different search terms including ‘free farrowing’, ‘pigs’ ‘sows’ ‘sus scrofa’ and ‘lactation/parturition and housing’ and ‘alternative farrowing and lactation’. Terms specific to farrowing systems include ‘temporary’ and ‘crate’ and ‘confinement’ and ‘farrowing’ and ‘loose lactation’ and ‘zero-confinement’, and ‘group farrowing/parturition/lactation’ and ‘multisuckling’ and ‘outdoor’ and ‘free range’. The research papers were supplemented by several relevant reports from academic and industry research programmes and industry trials (e.g. Pro-SAU, SEGES) known to the authors and relevant references cited in this report as well as other literature known to the authors was incorporated.

3.3. Screening and selection of evidence

All evidence was extracted and collated into a database (e.g. author, year, title, system, practice, data available per REA). Titles and abstracts were screened based on the relevance to the research questions. Literature was checked by collaborators who are specialists in the field to ensure all relevant papers have been captured and there was no bias.

3.4. Evidence appraisal

The selected evidence was critically evaluated based on the quality and appropriateness of its methodology (e.g. suitable experimental design to test the research question) and its relevance to the different research questions. For example, farrowing system and practice description (space, confinement or not, confinement period) are required as a minimum for inclusion in the appraisal. Where the initial screening process suggested data would be available to answer REAs, this was further checked to determine if there was enough information to determine effectiveness (i.e. is there enough information within the key performance indicators to determine levels of piglets survival?). Where possible data that could be used to model economic and environmental costs were also captured for the system. Where there was sufficient academic and industry research and published material, the evidence was progressed to inform narrative summaries.

3.5. Translation of REAs into narrative summaries

The REA synthesised all the separate findings for each system into narrative summaries of the evidence that answers the specific REA questions and enables conclusions to be drawn. These include a descriptive impact summary, an indication of the evidence quality and support for each farrowing system and/or practice, descriptive summaries of what the practice is, how effective it is, which contexts it works in, what best practice looks like, and links to further information. Where possible an estimated cost of implementation is provided.

4. Identifying systems and design considerations

4.1. Scoping exercise and terminology

Free farrowing is often used as an umbrella term to describe alternative farrowing and lactation systems to the conventional crate, however the terminology used is important to distinguish different designs and management practices. For indoor, single housing of sows and their litters the main management (and therefore design) consideration is whether or not you are retaining the ability to confine the sow in a crate. There are a wide variety of alternative farrowing and lactation systems that can be grouped within broader categories based on common features.

Temporary crating:
[Synonyms: Temporary confinement, loose lactation or free lactation].
The majority of these systems involve a widening of the existing farrowing crate to either allow the sow to be able to turn-around throughout farrowing and lactation or restrain the sow during farrowing before opening the crate up approximately 3 to 7 days post-farrowing. These systems range in spatial footprint from the same size as conventional farrowing crates (3.6-4.3m^2) to larger systems (7.4m^2).

Examples: ActiWel, Pro-Dromi®, SWAP, 360° Freedom Farrower™, Combi-flex, BeFree, SWAP:

Zero-confinement indoor:
[Synonym: Free farrowing].
The majority of systems involve the sow being housed individually whilst she gives birth and raises her litter. There are a variety of zero-confinement pens ranging in size and complexity but the main feature they all have in common is the absence of a crate in which to confine the sow during farrowing and lactation.

Examples: Danish Free Farrower, PigSAFE, SowComfort Pen, Swiss Free Farrower

Group:

[Other terms: Multi-suckle].
Group housing refers to a practice where sows are either i) grouped together before farrowing and have individual, voluntary access areas in which to farrow or ii) farrow individually and are then relocated and mixed into a group with other sows and litters (i.e. multi-suckling). In both situations the level of initial confinement may vary with sows either having free-access to individual farrowing pens, confined to individual farrowing pens or confined to farrowing crates.

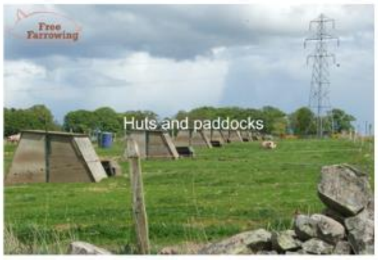
Examples: PureLine group lactation, Swedish deep litter

Indoor/Outdoor hybrid:
[Synonym: Kennel and Run]
An outside space is intended for dunging and feeding by the individually housed sow, with an indoor space (e.g. a kennel) for farrowing. Floors are typically solid to facilitate provision of substrate. A heated, creep space may be provided within the kennel for the piglets. Some organic systems operate these systems.

Examples: Kennel and Run straw pens, LSZ Boxberg (Organic, Germany), Solari-pen

Outdoor:
[Synonymn: Free-range, Outdoor bred, Organic[3]]
Sows and their piglets are housed individually, outdoors in farrowing arks or huts, with access to individual or group paddocks. There are different ark and hut designs available.

Examples: Individual huts/arks and paddocks



Each system then has extra levels of detail that determines its effectiveness including the quantity of space provided for the whole pen, the space for the sow and piglets as well as the quality of that space. In other words, design features or inputs that meet the animal's needs (e.g. flooring for substrate provision, separate microclimate for piglets) and staff needs (e.g. ability to separate staff from sows during husbandry procedures).

[3] Organic standards vary in different countries. In the UK organic production requires pigs to be housed outdoors (with shelter) throughout their lives. In Europe Organic standards permits some indoor housing for farrowing sows.

5. Critical review of the literature

In an original review of the literature on alternative farrowing and lactation systems (Baxter et al., 2012), 153 items were screened as yielding sufficient detail to provide information on different aspects of a range of systems, including design characteristics and performance data. The majority of information came from scientific papers (72%), with technical reports (13%), theses/dissertations (2%), conference proceedings and presentations (13%) also contributing to the database. Though there were differences in individual system designs, they could be grouped based on common features as described above. Zero-confinement systems were the most researched, followed by temporary crates, then group and outdoor. Since 2011 there has been a marked increase in research activity on alternatives, with 155 new articles found; publications relating to temporary crating have gone up by 139% compared to literature pre-2011. These systems have also received industry attention, with several large-scale commercial comparison trials completed in The Netherlands (e.g. Pro-Dromi® pen development), Austria (several pens tested in Pro-SAU); Denmark (several projects in the SEGES Danish Pig Research Centre) or on-going (e.g. Spain).

There are also a few commercial-scale trials looking at group-housed lactation systems (e.g. Pork CRC, Australia; Free Group Farrowing, Finland & The Netherlands; Inno-Pig, Germany) and projects focused on engagement activity across a range of stakeholders (e.g. 'Virtual Stable of the Future', Germany) to assist with transition. As well as data from the academic literature, final or interim reports from these large-scale commercial trials, we can look at data from the three countries where farrowing crates have been prohibited for some time (Switzerland, Sweden and Norway) where the predominant housing systems are single-housed zero-confinement pens. Whilst being mindful that there are national industry, political, legal standards and market differences that influence the success of these systems, there are still useful lessons to be learned from countries that have well established industries operating alternatives to farrowing crates.

For this REA we focussed on gathering and summarising evidence from **indoor** alternative farrowing and lactation systems.

5.1. Performance: Prevalence of mortality in different systems

Typically, the key performance indicators (KPI) reported when studying production aspects of farrowing systems are; total born, born alive, born dead, percentage pre-weaning or live-born mortality (i.e. piglets that are born alive but die pre-weaning), percentage total mortality (i.e. live-born deaths pre-weaning + stillbirths) and numbers weaned. Additional data that are sometimes, but rarely recorded consistently include sow condition (weight, condition score and back-fat) pre-farrowing and at weaning and piglet weight gain. There is, however, little consistency in what is reported and therefore any comparisons between studies should be treated with caution.

A number of review articles have already attempted to summarise performance information of alternative farrowing systems (Baxter et al., 2012; Pedersen et al., 2013; Glencorse et al., 2019), however, as these authors discussed, summarising information has a number of caveats, specifically that summarising can result in the loss of details of particular studies that might contribute to explaining performance figures. For example, breed differences, sow parity and previous experiences, the similarity between dry sow accommodation and farrowing accommodation have all been shown to influence piglet survival. In addition, when comparing housing systems, it should be the performance of the system that's compared, so including all piglets born in the system and analysis will be at the batch-level. However, when analysing information at batch-level, information about the individual litter cannot be included, so as supplementary analysis, piglet mortality at sow level can be analysed to learn about effects of things like littersize, parity, age at death etc. In many publications the focus is at sow level, which is more reflective of the sow and potential interactions between sows and piglets rather than the system. This could be particularly relevant when comparing performance in systems housing hyper-prolific sows because analysis at sow level will not include all piglets because some are moved to foster sows and if it does include all piglets, they will have experienced different conditions of either being raised by the biological sow or a nurse sow and moved to other litters during the lactation period. We therefore urge caution when looking at summary data.

Despite these limitations a key objective of this REA was to report the level of performance in alternative systems, particularly relating to piglet survival. Therefore in Table 1 we present the data acquired from our literature search from the last 10 years (2011-2021) and refer readers to previous detailed literature reviews summarising studies prior to 2011 (e.g. (Baxter et al., 2012; Pedersen et al., 2013)). The table provides the average percentage live-born mortality (LBM) and born alive from different studies comparing different alternatives with permanent crating of the sow.

Ten years ago, a summary table of performance from multiple articles and reports showed that zero-confinement systems (specifically 'designed pens'), swing-side temporary crates and conventional farrowing crates returned live-born mortality percentages of 12.0/11.7/11.1 and 11.2/11.9/11.1 and 11-13 total born respectively (Baxter et al. 2012). Table 1 shows the data from individual studies (comparing systems within study), organised by country of origin and author name. It demonstrates the variability amongst studies and the notable increases in average litter sizes over the last 10 years.

***Table 1**: Summary of live-born mortality (%) and born alive in studies comparing alternative systems: permanent crating vs. temporary crating; permanent crating vs. zero-confinement; temporary crating vs. zero-confinement; group vs. permanent crating. Reported significance of the difference is given as NS = not significantly different when compared, *** = highly significantly different (P<0.001), ** = moderately significantly different (P<0.01), * = significantly different (P<0.05). Note – sample size not always obvious per treatment – only given as indicator of study size.*

Authors and year	Source	Country	Permanent confinement			Temporary confinement			Zero-confinement			Group			Confinement period		Total space m^2	Space available to sow m^2	Reported significance of difference
			Live-born mortality%	Born alive	Sample size	Live-born mortality%	Born alive	Sample size	Live-born mortality%	Born alive	Sample size	Live-born mortality%	Born alive	Sample size	Days pre-farrow	Days post-farrow			
Morrison and Baxter 2012	Article	Australia	13.5	10.8	143				14.9	11.2	145						8.6	7.9	NS
Heidinger et al 2018	Report	Austria				11.0		*2069 total*	17.5		*2069 total*				-1	4	5.5-7.6		***
Heidinger et al 2018	Report	Austria				12.0		*2069 total*	17.5		*2069 total*				-1	6	5.5-7.6		***
Heidinger et al 2021	Presentation	Austria	11.9		*1319 total*	12.6		*1319 total*							-1	6	5.5		NS
Heidinger et al 2021	Presentation	Austria	11.9		*638 total*	12.4		*638 total*							-1	6	5.5		NS
Choi et al 2020	Article	China	12.3	9.0	11	17.0	9.9	11							-10	5	2.7	2.0	
Gouman et al 2018	Article	Czechia	10.5		14	9.8		14							-5	3	5.9	4.6	NS
Hales et al. 2014	Article	Denmark	12.6	15.2	68				14.2	15.1	275						5.4	4.5	***
Hales et al. 2014	Article	Denmark	12.1	15.6	268				15.8	15.4	238						5.2	4.1	***
Hales et al. 2014	Article	Denmark	10.7	14.8	297				11.7	14.7	222						6.3	5.3	***
Hales et al. 2015b	Article	Denmark	17.9	17.0	62	21.4	16.8	58	21.4						0	4	6.3	5.3	NS
Hales et al. 2016	Article	Denmark	6.5	17.0	19	5.5	16.5	19	8.9	16.8	20						6.3	5.3	NS
Moustsen et al 2013	Article	Denmark				6.8	14.8	51	15.2	14.5	55				-5	7	4.7		***
Moustsen et al 2013	Article	Denmark				8.2	14.7	50	15.2	14.5	55				0	4	4.7		***
Moustsen et al 2013	Article	Denmark				8.2	14.6	54	15.2	14.5	55				0	7	4.7		***
Yun et al. 2014	Article	Finland	12.8	12.2	12	15.1	11.3	11							0	7	7.0	4.8	NS
Yun et al. 2014	Article	Finland	12.8	12.2	12	11.3	11.7	10							0	7	7.0	4.8	NS
Bohnenkamp et al. 2013	Article	Germany	15.7		52	14.7		51							-3	1	17.7	4.7	NS
Grimberg-Henrici et al. 2019	Article	Germany	19.0	17.4	63							28.30	17.40	40.00			8.3	4.0	***
Grimberg-Henrici et al. 2019	Article	Germany	19.0	17.4	63							35.90	17.40	40.00			7.1	3.6	***
Höbel et al 2018	Article	Germany	18.3	15.7	38	19.7	16.0	38							-5	10	6.9	3.7	NS
Höbel et al 2018	Article	Germany	18.3	15.7	38	19.2	14.7	37							-5	10	5.5	2.7	NS
Lohmeier et al 2020	Article	Germany	16.1	18.1	79	20.1	16.3	47							-1	4	7.0-7.6	3.2-4.3	*
Lohmeier et al 2020	Article	Germany	19.3	17.7	126				27.5	16.8	121				0	0	7-7.6	3.2-4.3	NS
Nicolaisen, et al. 2019	Article	Germany	12.3	14.9	53				25.6	14.2	49						7.3	6.5	*
Nicolaisen, et al. 2019	Article	Germany	12.3	14.9	53							19.90	15.80	54.00			19.3	5.0	*
Schnier, et al. 2019	Article	Germany	13.2	14.8	51				24.4	14.2	47						7.3	6.5	*
Schnier, et al. 2019	Article	Germany	13.2									20.90	15.80				19.3	5.0	*
Spindler et al 2018	Field trial	Germany	24.2	14.9		22.5	15.1								-5	7			NS
Kinane et al 2021	Article	Ireland	14.4	14.8	24	15.9	14.6	22							-1	4	5.5	3.4	NS
Chidgey et al 2015	Article	NZ	6.1	11.9	333	10.2	11.9	394							-5	4	5.9	5.0	***
Chidgey et al 2016a	Article	NZ	10.0	11.1	123	11.8	10.9	69							-5	4	5.9	5.0	NS
Condous et al 2016	Article	NZ	15.6	11.9	53	15.1	12.9	36							-5	7	6.0	4.9	NS
Condous et al 2016	Article	NZ	15.6	11.9	53	17.2	12.2	16							-5	3	6.0	4.9	NS
Condous et al 2016	Article	NZ	15.6	11.9	53	19.6	12.5	35							0	7	6.0	4.9	*
Condous et al 2016	Article	NZ	15.6	11.9	53	30.9	12.1	20							0	3	6.0	4.9	*
Olsson et al 2018	Article	Sweden				19.4	14.5	157	26.6	14.2	161				0	4	6.0		***
Lambertz et al 2015	Article	The Netherlands	11.4	12.8		13.3	12.8								0	7	4.6	2.8	NS
Lambertz et al 2015	Article	The Netherlands	11.4	12.8		12.9	12.8								0	14	4.6	2.8	NS
Edwards and Baxter 2015	Report	UK	9.0		164				9.6		140				0	0	7.6	6.9	NS
King et al 2019a	Article	UK	12.3			13.0									-5	10	4.6	3.8	NS
Loftus et al 2020	Article	UK	8.1	12.8	12	8.9	13.1	12							0	5	5.6	3.2	NS
Ceballos et al 2021	Article	USA	25.9	14.5	177	27.8	14.4	185							-2	4	4.2	3.3	*
Ceballos et al 2021	Article	USA	25.9	14.5	177	23.9	13.8	161							-2	7	4.2	3.3	NS
Mack et al 2017	Case Study	USA	8.2		19	17.2		19							-5	14	4.1	3.6	***
Mack et al 2017	Case Study	USA	12.7	13.0	19				26.7	13.4	30						7.1	6.3	**

5.1.1. System differences in live-born mortality

Temporary crating (TC)

Most studies (13 of 19) reported no differences in preweaning piglet mortality rates in temporary crates compared to farrowing crates (Table 1). Two studies showed no difference between temporary crates and zero confinement (e.g. Höbel et al., 2018; Hales et al. 2015b). Two studies observed a decrease in piglet mortality in temporary crating (Olsson et al., 2018; Morgan et al., 2021). This latter study was within farm looking at different periods of temporary crating rather than comparing with another system (so not in the table). Other studies have reported an increase in piglet mortality after the crate was opened from d4 post-farrowing (Chidgey et al., 2015; Ceballos et al., 2021) compared to sows permanently crated. King et al. (2019b) recorded higher mortality rates post vs. pre-crate opening within the same temporary crating system. A study that temporarily crated the sows in farrowing crates before moving them to group lactation pens on either day 7, 10 or 14 post-farrowing, found higher mortality compared to permanently using farrowing crates (Verdon et al., 2020). On the other hand, Bohnenkamp et al. (2013), using temporary crating then grouping, saw no differences (Table 1). There was no relocation of groups in this study though and almost immediate voluntary access to the communal area for sows using a specialised voluntary access temporary crate from day 1 post-farrowing. Spikes in mortality in two-stage lactation systems are commonly reported (see Groups below).

Timing and causes of mortality in TC: Where the causes of mortality have been studied in more detail, it is deaths attributed to crushing which show the greatest increases in sows which remain unconfined (Condous et al 2016; Heidinger et al 2018; Olsson et al 2018), although this was not the case in all studies (e.g. Condous et al., 2016; Spindler et al., 2018).

Crated sows show a reduced frequency of posture changes during farrowing (Heidinger et al 2018; Nowland et al 2019), although data are conflicting regarding the first few days after farrowing. Studies report both fewer (Hales et al 2016) or similar (Heidinger et al 2018) frequency of posture changes when comparing sows confined before farrowing with unconfined sows, and in some cases (Heidinger et al 2018), but not others (Nowland et al 2019), an increased frequency when sows are confined shortly after completion of farrowing. The post-farrowing period is characterised by prolonged lateral lying by the sow (Hales et al., 2016) as an important maternal behaviour to safe-guard her piglets, therefore even small numerical changes can be statistically significant. These studies looking at sow activity in the first few days after farrowing are important when informing the potential for welfare impacts when using temporary confinement (see section 5.2) and when determining the period necessary for confinement.

It has been reported that significantly more piglets are crushed with earlier opening of the crate (Table 1: Day 4 vs. 7; Ceballos et al., 2021; Day 4 vs. permanent - Lohmeier et al., 2020). However, since the majority of liveborn piglet mortality in all systems is reported to occur in the first few days after farrowing (Edwards, 2002), there is debate about the period of time for which it is necessary to confine the sow. Table 1 gives data about confinement period and mortality levels which contributes to this discussion (as does data summarised in Section 5.2.1). Caution should be taken when using this table to make comparison given that the absolute level of mortality varies widely between studies, reflecting differences in genetics, pen designs, quality of environment and management. Closer inspection of studies is required to provide an evidence-based summary. Looking at large within study comparisons is the most appropriate method and perhaps the most informative study tackling this critical window of confinement between d4-7 is the Pro-SAU project (Heidinger et al., 2018). They compared a crate opening time of 3 or 5 days with ~160 sows per treatment distributed across 5 different TC pen designs and concluded that no reduction in mortality resulted from the additional 2 days of confinement (11 vs 12% of mortality for 3d and 5d respectively). Similarly, Moustsen et al. (2013), with 55 sows per treatment, found no improvement in survival when comparing release on d4 or 7 post-farrowing. However, Ceballos et al. (2021) did find a significant difference in mortality when comparing 4d and 7d TC with 161-185 sows per treatment, although with an atypically high overall mortality level (27.8 vs 23.9% mortality).

Zero-confinement (ZC)

What is apparent in the literature already summarised (Baxter et al., 2012; Pedersen et al., 2013; Glencorse et al., 2019) and in studies with comparisons between systems shown here (Table 1) is that different systems show a great deal of variability in their performance with some reporting no differences between systems and others reporting higher mortality in pens compared to crates (e.g. Table 1).

Many of the studies are using an open temporary crate as the zero-confinement option and some of these systems involve quite a basic design on a small footprint. Yun et al. (2019) only monitoring mortality during the first 24h post-farrowing saw significantly higher mortality rates in hyperprolific sows farrowing in open crates compared to closed crates (17.9% vs. 1.4% with litter sizes of 19.3 and 18.1 respectively). The authors cite the small space in the swing-side crate as a potential contributing factor offering piglets little escape room and sows little room to move away or gather piglets safely before lying down. Bolhuis et al. (2018) also looked at piglet mortality in a TC pen in an open position for the first 48h. This pen was larger with some design features and resources that might aid sow posture changes, such as sloped walls and plentiful nest-building material. When comparing performance over that period with crated sows they demonstrated that substrate and housing influenced the farrowing process independently rather than additively. There was less activity from the sows that had nesting material but overall greater mortality in the loose pens for the first 2 days (Bolhuis et al., 2018). This shows the benefits of providing substrate to stimulate good maternal behaviour but limitations in how much it can mitigate for pen size and large litters; when the sow has a large litter sharing a small space without any supervision/intervention to reduce litter size the risk for mortality is high.

Solutions for large litters involve a range of practical interventions (Baxter et al., 2013), but can also include pen innovations, however, getting the details right is critical to help mitigate the impact of large litters. For example, during the critical period when piglets are sharing the sow space immediately post-farrowing the risk of crushing is high, however if the space is too large there are also mortality risks due to the distance to safety zones/supplementary heat sources being too large for the piglets to find easily and it increases the piglets risk of being overlain (Baxter et al., 2015). Optimising piglet protection features and safe-zones at piglet height will reduce the risk of crushing by rolling whilst not compromising space too much to accommodate unobstructed sow turning circles (e.g. sloped walls) and encouraging piglets to find the creep by positioning it close to the intended farrowing location of the sow (e.g. corner creep running parallel to the udder) (Damm and Nielsen, 2000), as well as creating temperature differentials via ambient temperature and flooring that make the creep more attractive.

As noted in the TC section crushing mortality is generally reported as higher in loose housed sows than in those that are crated. However, death due to “other” causes (e.g. starvation, low viability/poor doer, scour) are reported as being more prevalent when sows are crated (e.g.(Weber et al., 2007; Kutzer et al., 2009)) and death due to savaging is reported to be more likely in sows who are crated compared to those loose (Lawrence et al. 1994; Ison et al. 2015). Savaging is a complicated behaviour typically seen in gilts, but one reason for its higher prevalence in crates is the impact confinement has on thwarting nest-building behaviour and the accompanying hormonal response preparing the sow for farrowing and promoting passivity during farrowing (Algers and Uvnäs-Moberg, 2007). It is a myth that gilts in loose systems do not savage and the potential for them to cause significant damage is high with no restriction if they did want to damage piglets. However, it appears they settle down quicker than gilts in crates displaying savaging where the mismothering was observed for longer (Ison et al. 2015). There could be genetic elements to savaging, Danish herds very rarely experience this issue (Moustsen pers comm).

Group-housing (GH)

There is very little comparative data on performance in group housing accommodation. Long-term performance monitoring of a group farrowing system at the University of Minnesota over 13 years has seen live-born mortality fluctuate between 18-30%, averaging between 20-25% (Li, 2021). They state the system is affected by season and parity with higher mortality in summer and greater piglet losses from higher parity sows. Although there are no comparisons with crates from this group, the researchers suggest the high pre-weaning mortality is due to the group-housing and lack of piglet protection features in the farrowing boxes. There have been a number of projects in Germany, the Netherlands and Australia looking at two-stage and multi-suckle systems. Mortality results suggest that performance is still poor compared to conventional or individual farrowing pens (van Nieuwamerongen et al., 2014).

5.1.2. System differences in stillborn mortality

It is often reported that there is a greater incidence of stillbirth in crated systems compared to when the sows can farrow loose (e.g.(Jarvis et al., 1999; Marchant Forde, 2002; Oliviero et al., 2010; Condous et al., 2016; Choi et al., 2020)). However, this is not always the case with many studies showing no effect on stillbirth (Cronin et al., 1996, 2000; Marchant et al., 2000; Weber et al., 2007; Moustsen et al., 2013; Bohnenkamp et al., 2013; Hales et al., 2014). For some of these studies showing no effect the sows were loose up until day 114 of gestation, provided with nesting material and then confined in a temporary crating design, rather than a conventional crate. So, the design could already be less restrictive even though classed as a crate. The multifactorial nature of piglet mortality means it is not surprising that there are mixed results when looking specifically at system's differences in stillbirths. Longer farrowing durations are associated with stillborn mortality and farrowing duration can be affected by a number of biological and environmental factors. These include litter size, sow energy levels, therefore nutrition and there are links with stress and therefore the positive effects nest-building can have on reducing stress (Yun and Valros, 2015), but also the impacts positive human-animal relationships and specific management routines in loose housing (Rosvold et al., 2017) can have on stress and piglet mortality. Mitigation of stillbirth is likely to be as multifactorial as its causes.

5.1.3. Commercial data from countries prohibiting farrowing crates

Successful adoption and consistent performance have been reported in some countries operating non-crate systems for a long time.

Swiss regulations: Switzerland has had a ban on farrowing crates since 1997. Their animal welfare law states that pens must be big enough for the sow to be able to turnaround freely. For pens installed prior to 2008 the minimum footprint is 4.5m^2. Pens installed after 2008 must be a minimum of 5.5m^2 with at least 2.25m^2 allocated to the sow lying area. There are specific regulations about solid flooring, providing 'suitable' nest-building material from 2 days prior to farrowing and provision of enrichment material during lactation. 'Suitable' nesting material has to be something that can be carried 'by the snout' not chopped straw, not sawdust but long-straw. There is a stipulation that if sows are savaging or if they have lameness problems you are permitted to temporarily crate her for farrowing. However, these are the only reason to restrain the sow and it can only be temporary from the beginning of the nest-building period until the end of the 3rd day following birth.

Swiss systems: There are a variety of pen types with each company offering its own 'brand' (Weber pers comm, 2021). For pens operating truly free farrowing with no possibility to confine, producers mainly operate the 'FAT2' type pens which has a divided dunging and lying area on a footprint of 7m^2.

Swiss performance: There was a 10-year transition phase from the announcement of the ban on crates in 1997. During that window data were collected from farms operating crates and zero confinement. Data from 655 farms comprising 63,661 litters demonstrated that piglet losses in loose farrowing pens were no greater than in farrowing crates (Live-born mortality: loose = 9.6% (±0.02) from 18,824 litters and Crates = 9.6% (±0.01) from 44,837 litters). This was from litters averaging 11.6 total born. Since then, data have been collected from over 330,000 litters from 255 free farrowing farms and comparing those figures from 2003 with data from 2008 to 2017 they report significant increases in average litter size (total born = 11.7 in 2003 and 13.8 in 2017) but no differences in mortality (live-born mortality = 11.7% in 2003 vs. 11.1% in 2017 - (Weber et al., 2020)) Cautious optimism should be applied when looking at the Swiss figures captured during the transition phase because it is not necessarily representative, given that older crates were being replaced with newer pens and 'new-building effects' may be having an influence. However, the latest data suggests consistently good performance (Weber et al. 2020).

Norwegian regulations: Norway has had a ban of farrowing crates since 2000. There is a minimum footprint of 6.0m^2 and temporary confinement is only allowed if sows are aggressive and only for a maximum of 7 days post-farrowing. Standard loose housed pens are typically larger at 7.7m^2 including the creep. Farrowings are attended and no drugs (e.g. oxytocin) can be given unless by a vet. There are recommendations for providing nesting substrate and legislative minimums for sawdust provision to maintain hygiene (Inger-Lise Andersen pers comm 2021).

Norwegian systems: There are a variety of pen-types. Researchers at the Norwegian University of Life Sciences have been developing the Sow Comfort Pen for a number of years with a Norwegian equipment company that measures 7.7m^2 with no possibility to crate the sow, but separate dunging and lying areas (Andersen and Ocepek, 2020) with a step-down into the dunging area for full separation. There is now interest in Norway to build larger farrowing accommodation (8-9m^2) to house from birth to 30kg weaner, thus by-passing the specialist weaner facility.

Norwegian performance: National annual statistics (INGRIS Årsstatistikk, 2020[4]) reports total mortality as 18.3%, live-born mortality just over 12% with 15.7 total piglets born, weaning age is 33 days. A large study of pre-weaning mortality examined causes of death on 14 loose-housed Norwegian herds (Kielland et al., 2018) and reported higher than the national reports with total mortality at 23.4%. The authors noted that this figure was comparatively low compared to reports of 24.7% in a similar study 30 years previously when farrowing crates were the main farrowing system (Grøndalen et al., 1986).

Swedish regulations: Sweden was the first country to restrict the use of farrowing crates in 1987 (the 'Lex Lindgren' legislation). The pens have to be a minimum of 6m^2 (including a creep) with a minimum lying area for the sow of 4m^2 and 75% of the lying area must be a 'non-draining' floor. There is a stipulation in the Swedish regulations that allows temporary crating in special cases – e.g. "only sows that are aggressive towards their piglets or show abnormal behaviour that presents an obvious risk to the piglets can be confined". However, it is not stipulated for how long this derogation is allowed. It does state that 'before farrowing, sows and gilts shall be able to move freely in the farrowing pen, so that they can perform nest building' and there are regulations stipulating that sows must have access to 'litter that enables them to perform nest-building' (SJVFS 2010:15 (L 100)).

Swedish systems: Typical Swedish systems are varied but similar to those developed in Norway and Switzerland to accommodate the regulations for substrate provision and a solid sow lying area. Early in adoption of free farrowing regulations a number of producers developed group housing with free-access or separate nest-boxes and a communal suckling area (e.g. Ljungström, Thorstensson) and some of these are still in operation but individual farrowing pens are more typical. As some temporary crating of sows is permitted 'in special cases' these systems can be found on farm.

Swedish performance: Sweden has seen piglet mortality levels rise in the last 10 years, in part a facet of increasing large litter size (Andersson et al., 2015), although national herd data from several countries suggests Sweden's mortality levels compared to litter size is an outlier (InterPig data, 2019). Large litters have a known association with piglet mortality and a recent Swedish study comparing performance in temporary confinement and loose systems highlighted that, regardless of farrowing system, more piglets died in large litters compared to small ones (Olsson et al., 2018).

The consistent production of supernumerary piglets (i.e. piglets in excess of the number of functional teats) requires significant interventions by staff to promote survival. This is perhaps one of the major barriers to adoption of a truly free farrowing system (i.e. zero confinement throughout farrowing and

[4] https://norsvin.no/ogroothe/2021/04/Arsstatistikk-2020-007-endelig.pdf

lactation), along with concerns about costs, not only of installation but for long-term production. Producers want to retain the advantages of the crate in controlling sow movement (to reduce crushing) and allowing localised heating at the birth site, and to facilitate safe targeted interventions by staff to promote piglet survival such as assisted suckling, split suckling and cross fostering. All of these tasks are needed more as a result of the increased prevalence of very large litter sizes. These are most likely the predominant reasons why systems that permit use of a crate temporarily are becoming more popular and why Austria and Germany are permitting 'crating during the critical period for piglet survival' within their legislation (4 and 5 days maximum respectively) and why Denmark (the country most renowned for large litters) has pledged 10% of its herd will be loose lactation by 2022, thus also permitting the temporary use of crates. It is therefore not unsurprising that the majority of new research has had a focus on temporary crating.

5.1.4. Summary on systems and piglet mortality

- Performance is highly variable from system to system, farm to farm and country to country.
- Large litter size significantly increase mortality in any system but zero-confinement around farrowing, before litter equalisation, constitutes a high risk of mortality. There could be a pen size effect whereby small TC systems operated as ZC pose a greater risk to mortality.
- Removing confinement after 4 days is good practice if the piglets are strong and using the creep (see Pen design section).

5.2. Welfare impacts and opportunities in alternative systems

5.2.1. Piglet welfare challenges and opportunities during farrowing and lactation

The main welfare challenges for piglets are the pre-disposing risk factors for mortality. The most vulnerable period is during the first 3 days of life, when they can suffer oxygen deprivation from birthing difficulties, hypothermia, crushing and starvation. These early causes of live-born mortality are often interlinked, and many piglets will become chilled, fail to compete at the udder for colostrum and lack energy to move away from the sow when she changes posture (Edwards, 2002). Piglets can also suffer from disease pre-weaning, especially if they fail to suckle colostrum from which they gain passive immunity. Thus, many piglets that die pre-weaning are likely to be exposed to some degree of either pain, hunger and/or fear and stress which could be either acute or chronic. Piglets that are born dead are unlikely to have reached a conscious state and therefore stillbirth is less of a welfare issue for the piglet itself (for a more detailed discussion see (Baxter and Edwards, 2018)).

Many of the pre-disposing risk factors for mortality have been exacerbated by breeding for large litters and lean tissue growth rate, which reduce piglet maturity at birth and increase within-litter competition both pre- and postnatally. As piglet survival is the dependent on the sow, piglets and their interactions with their environment, pen design and resources within that pen (e.g. supplementary heat) can impact welfare. As large litters require more managerial inputs, stock people and how they interact with the animals can influence welfare and these are affected by pen design.

Piglets also experience welfare challenges when they undergo routine and permitted husbandry procedures usually within the first 3 days of life. These involve handling by staff and how easily this is achieved is impacted by the pen design and maternal behaviour (also interacting with features of pen design).

Piglets can experience further welfare challenges, including behavioural detriments as a result of barren housing environments, with little or no access to environmental enrichment or structurally complex surroundings that are known to have positive effects on social and cognitive development ((De Jonge et al., 1996; Martin et al., 2015), adaptation to weaning (Oostindjer et al., 2011), growth rate (Brown et al., 2015), immune responses (van Dixhoorn et al., 2016; Luo et al., 2017) and stress regulation mechanisms (Fox et al., 2006). Piglets reared in barren environments often develop poor social skills, display abnormal behaviours both pre- and post-weaning, and lack behavioural flexibility to cope with challenges later in life. Therefore, opportunities for welfare enhancements can come from the choice of farrowing system and the resources provided within it, particularly environmental enrichment. Indirect opportunities to mitigate welfare challenges that relate specifically to farrowing systems include the impact design features and components can have on stimulating positive maternal behaviour and the impact design has on ease of management (Section 5.3).

5.2.1. Sow welfare challenges and opportunities during farrowing and lactation

The choice of farrowing system is one of the major factors in determining welfare challenges for expectant sows. Systems that impose restriction of sow movement interfere with the performance of species-specific behaviours such as nest-building, orientation, exploration and communication with the piglets and leads to increased physiological stress. These are all well documented and reviewed already (Pedersen et al., 2013b; Baxter et al., 2018). The system also impacts welfare outcomes post-farrowing as it can interfere with normal social behaviours and how well sows do when they are weaned and mixed with other sows. Designing systems that allow more natural pre-wean interactions can reduce the aggression and stress inherent with the formation of new hierarchies when weaned (Greenwood et al., 2019). As the pen design can influence ease of management there is potential for welfare detriments if the human-animal relationship is strained and there are particular trade-offs associated with staff needing to attend to piglets and the risk of sows being maternally defensive.

The potential welfare impacts and opportunities for welfare enhancements relating to farrowing and lactation for both sows and piglets have been summarised using a five domains approach (Mellor, 2016; Mellor et al., 2020) as requested by the tender. The 5 domains relate to physical (or functional) factors (Domains 1-4) and how they impact on mental experiences (Domain 5) and can be used to assess welfare systems and practices. We have generated ‘domain tables’ summarising each potential negative and positive aspect for sows and piglets. These tables are comprehensive and could allow application of the 5 domains model to assess system scenarios in the future but not in the limited time for this REA. The tables and details are in Section 8. Here we will concentrate on summarising the evidence of how pen design features impact on welfare and welfare challenges and opportunities are also covered elsewhere in the REA as they overlap with discussions on mortality, staff welfare and in the narrative summaries.

5.2.2. Pen design

Ensuring maximal welfare in the farrowing and lactation environment involves identifying the biological needs (i.e. physiological, physical and behavioural necessities) of the pigs and then determining the best way to meet those needs. This has been extensively researched and the evidence base is discussed elsewhere (Baxter et al. 2011; 2012; 2018; Pedersen et al. 2013). Here we attempt to summarise this work by provide a table of system components required to meet the biological needs of the sows and piglets (Table 2 - updated from Baxter and Edwards, 2021). This gives some reference values that can be used to determine the welfare impacts and opportunities in alternative farrowing systems based on their design components (e.g. space, flooring, walls) and resource provision (e.g. substrate) and how they interact. It should be noted that the biological needs are not ranked – the list is arranged based on the timeline of farrowing and lactation: incorporating the pre-farrowing period of nest-seeking and building, parturition, early lactation and late lactation. It is out with the scope of this review to provide any discussion on ranking of biological needs but having reference values (for these design features and resource components) helps determine the potential welfare consequences and enhancements in alternative farrowing systems.

***Table 2.** Updated summary of sow' and piglet' biological specifications for a farrowing and lactation system and estimated "values" required to meet their specifications/needs (adapted from Baxter and Edwards 2021). The values/design criteria are determined from empirical studies looking at physical (e.g. body dimensions), physiological (e.g. thermoregulation) and behavioural (e.g. observations of nest-building, mother-young interactions) attributes of the pigs and how they interact with their environment during this period (Baxter et al., 2011). More detailed descriptions are given in Baxter et al. (2011 and 2018) where explanations and evidence for values are described. Any new information published since these manuscripts has been incorporated. Where no new information has materialised and values for components cannot be given, "further research" is noted. Please note each line is a different biological specification and its corresponding 'value' is described only for that line (i.e. space recommendations aren't cumulative – they describe the space required for that function/activity based on allometric equations).*

Component of system	Sows	Value of required specification at minimum level to meet needs		Piglets	Value of required specification from minimum to ideal level
Space	Increased activity for nest-site seeking	4.9m^2 (note this is minimum for this activity not necessarily total area)		Parturition	2.79m^2 (based on allometric equations for sow lying laterally and space for giving birth without obstruction)
	Hygiene – separate dunging space from feeding and lying area	Separate dunging area from nest and feed sites.		Udder access for suckling throughout lactation	2.79m^2 (based on allometric equations for sow lying laterally and piglets being able to walk around sows and access udder)
	Feeding and foraging	Separate feeding area from nest and dung sites		Protection, safe lying area for parturition and nest-occupation	Separate space inaccessible to the sow e.g. 0.8m^2 per 10-12 neonates, 0.96m^2 for 14, four-week-old piglets (based on measurements of piglets at 4 weeks old in lateral or semi-lateral lying positions)
	Turn-around nest space for piglet inspection and gathering behaviour	Planar space (i.e. space at sow shoulder height) = 3.17m^2. Based on extrapolated allometric equations and measurements of body length and width of modern commercial sows. *Needs further investigation*		Area for feed trough to introduce starter diet and area for supplying supplementary nutrition/energy (separate from the sow)	Provide in the creep, interacts with above
	Lateral lying and parturition	2.79m^2 (based on allometric equations for sow lying laterally and space for giving birth without obstruction)		Hygiene	Separate area for dunging, interacts with flooring
	Thermal comfort via posture changes	2.44m^2		Engage in social and locomotor play	Dynamic space to run and play and invite or reject play behaviours between conspecifics

		(based on allometric equations for sow lying laterally – i.e. to dissipate heat)			
	Nest-departure	Separate area from nest site			
	Gradual separation from piglets and sow-controlled nursing	Separate space inaccessible to piglets			
	Social contact with other sows	Separate space inaccessible to piglets to allow contact between sows, but if sows fully reintegrated before weaning larger space to allow body language assessment and/or fighting to establish dominance – further research needed to determine minimum space per sow.			
Substrate	Nest-building - carrying and manipulating	2kg long stemmed straw		Foraging, nutritional development	Earth-like materials (e.g. peat) *Further research needed on quantity*.
	Complete nest	2kg long stemmed straw and additional materials that can be carried, arranged, rooted		Enrichment, social and cognitive development	Novelty requires fresh input daily. Complex materials (e.g. branches) preferred.
	Udder comfort	*Further research needed* interaction with floor properties		Thermal comfort during parturition	2.5cm of straw, interacts with flooring
	Thermal comfort during nest-building and parturition	2kg long-stemmed straw in nest site – interaction with flooring and room temperature.		Physical comfort	*Further research needed*, interacts with thermal comfort and flooring properties
	Foraging material	*Further research needed*		Protection	Deep bedding: 10-12cm, interacts with flooring
Walls	Enclosure/Isolation of nest	3 solid-sided walls (cul-de-sac)		Protection from sow posture changes	Sloped wall
	Visual and physical contact with non-litter sows	Vertical barred area with void wide enough to allow at least nasal contact between pigs		Social contact with non-litter pigs (visual and physical)	Vertical barred area
	Hygiene	Solid at base with separation between pens		Hygiene	Solid walls (at least at bottom of penning) separating other litters
	Supported posture changes	Solid sloped or vertical walls		Thermal comfort	Solid walls with thermal resistance properties to limit heat loss via radiation – interacts with substrate and flooring
	Lack of disturbance	*Further research needed*, interacts with general features of room		Reduced fear response to humans	Lower walls in creep passageway side to facilitate easy human

		Interacts with room design and pen number per room and human-animal interactions			handling and reduce necessity for chase and catch
	Ability to see staff approaching	Correct height to allow isolation but reduce fearfulness by unexpected appearance of people. Interaction with general features to promote ease of management			
Flooring	Nest-building - digging, rooting and hollowing	Malleable (e.g. earthen) or solid to accommodate deep substrate		Thermal comfort during parturition and first 24h of life	High thermal resistance - e.g. rubber matting or deep substrate or under-floor/localised heating
	Nest-building and parturition	Solid to accommodate substrate *Needs further research*		Thermal comfort during lactation	High thermal resistance - e.g. rubber matting or deep substrate (see above) or under-floor/localised heating (see general)
	Thermal comfort during nest-building, parturition and lactation	Temperature differentials in separate areas allowing choice High thermal resistance e.g. rubber matting or deep substrate. Low thermal resistance e.g. metal.		Physical comfort - avoiding injury, promoting suckling behaviour Protection from fatal crushing by the sow	Solid flooring with minimal abrasiveness and well maintained (e.g. rubber matting or specialised screed with non-slip properties), interacts with substrate
	Physical comfort - avoiding injury, promoting suckling behaviour	Non-slip surface, supportive structures under flooring to accommodate increased 'traffic' in pen and reduce risk of flexing that can induce insecurity. Minimal abrasiveness (interacts with substrate). Solid to avoid teat injuries. *Needs further research*		Hygiene	Slatted flooring with void width no more than 10mm and rounded edges. Interacts with temperature (see general)
	Hygiene	Slatted area Gradation of floor with slope away from lying area. Dung shoot in pen for ease of removal during mucking out. *Needs further research*			
General and farrowing room considerations	Thermal comfort	Ambient temperature 12-22°C, interactions with substrate, flooring, walls and ventilation		Health - treatment for injuries, vaccines, etc	Safe area for handling required, interacts with space
	High feed intake	See space and thermal comfort Fresh water supply, optimal flow rate (2litres/min for nipple drinkers) Clean food trough		Promote weaning, reduce nutritional stress and encourage increased feed and water intake	Suitable solid food - interacts with space and substrate Provide feed tray and sufficient space to allow social facilitation.

		Optimal feeding provided for stage of lactation			Consider family feeding system where piglets learn from their mothers
	Low light in nest	Suitable light placement in room but enough light for inspection purposes		Thermal comfort	Localised heat source set at thermo-neutral temperature (e.g. 34°C at birth) – interacts with substrate, ambient temperature, flooring, walls
	Physical comfort – avoiding injury	Fixtures and fittings are non-injurious, no sharp corners/edges, protrusions		Hygiene	Temperature differentials to encourage dunging outside of nest site – interacts with flooring
	Ease of management	Multiple entry and exit points into pen to aid ease of loading and unnecessary interaction when in pen- interacts with walls Number of pens per room considered for promoting quietness and easier batch management Method to separate sow from staff temporarily Design features that promote hygiene, easy birth assistance, provision of nesting substrate. Interacts with slurry system and flooring		Ease of management	Lockable creeps with ventilation gap to aid creep training without excessive handling Easy access to creep from passageway to reduce need for pen entry Design features that promote hygiene, easy birth assistance and delivery of piglet survival interventions, provision of enrichment material/items – e.g. point source attachments. Interacts with slurry system and flooring

Pen designs referred to in most peer review publications consist of compromises and few if any meets all design criteria as detailed in Table 2. In addition, not all pen details are described in publications. This makes it difficult to compare the pens and to provide specific recommendations.

Overall, there are pens with a focus in the design on the loose sow and the litter and where temporary confinement is an add-on in the aim of reducing the risk of neonatal piglet crushing (e.g. (Hales et al., 2016; Goumon et al., 2018). Other pens are closer to traditional farrowing crates (Moustsen et al., 2013; Morgan et al., 2021; Nowland et al., 2019), with limited innovations to meet the sow and piglet behavioural needs (Nowland et al., 2019).

The majority of recent research on alternative systems has been concerned with the level of confinement and how it impacts on welfare, performance and manageability. Given its importance in the discussion around alternative systems it warrants more in-depth review that then informs the narrative summaries.

5.2.1. Confinement

The majority of the welfare discussion about temporary crating (TC) systems will be about confinement. Other design aspects of the pen could be common to all systems and therefore elements of welfare discussions will overlap in this section. Aspects only relevant to TCs however are how much the crate is utilised, and the specific timings for closing and opening - all have been shown to have an impact on both sow and piglet welfare.

Timing of confinement: A reduction in confinement will be beneficial for the sow. However, decisions on when to confine and when and how to release has impacts on the acute stress response of the sow and on piglet survival. The impacts when she is confined are the thwarting of highly motivated nest-building behaviours. The risks of leaving her unconfined are that there is less control over her posture changes and therefore a greater risk of piglets being crushed, especially when there are large amounts of piglets sharing the same space as the sow (Yun et al. 2019). Ability to offer targeted supplementary heating at the birth site is also prevented when the sow is loose during farrowing and any management interventions will be risky, even though the period during farrowing is characterised by more passive behaviour displayed by the sow.

There is evidence of a stress response (increased plasma cortisol levels) when gilts are moved from their loose gestation housing 5 days before their due date that lasted at least 18h (Lawrence et al., 1994). Moving gilts and sows too late into farrowing accommodation also showed a stress response (Pedersen and Jensen, 2008), with gilts moved late into crates showing longer farrowing durations and higher stillbirths than gilts moved late into pens. Disturbing sows during farrowing impacts farrowing duration and so does shutting them into crates at this time (Yun et al., 2015a). Another study moved sows into loose accommodation with nesting material and then confined 2d before their due date and found no effects on salivary cortisol response or on farrowing progression, but it did influence nest-building behaviour (Hansen et al., 2017). Hales et al. (2016) reported that confinement prior to farrowing resulted in a decreased frequency of nursing bouts in the following 2 days.

Impact of temporary confinement on nest-building: In a large study involving five different TC pen designs, Heidinger et al. (2018) showed that the duration of nest building and the time active during the nest building phase were reduced in sows confined 1d before expected farrowing in comparison with sows confined after completion of farrowing or never confined. Thwarting nest-building by restricting space and substrate availability leads to increased stress, particularly in gilts (reviewed in Baxter et al. 2018) and it appears lack of space is more stressful than lack of substrate (Jarvis et al., 2002). In a study where no nesting substrate was provided, confining sows from 6d prior to expected farrowing resulted in increased nosing of crate features, though not bar biting (a behaviour associated with frustration - (Yun et al., 2015b)), during farrowing in comparison with sows confined after completion of farrowing (Nowland et al., 2019).

The impact of timing of confinement on farrowing duration and the potential for stillbirths are inconsistent. Three studies show increased stillbirths in sows crated for >2d before expected farrowing (Condous et al., 2016; Choi et al., 2020; Nowland et al., 2019). Six studies, however, reported no difference in stillbirth rate (Lohmeier et al., 2020; Hales et al., 2015a,b; Hales et al., 2016; Moustsen et al., 2013; Hansen et al., 2017). In the case of the 2 studies in which confinement was imposed shortly (1d or less) before expected farrowing, there was no difference in stillbirth rate when compared to unconfined sows (Lohmeier et al., 2020; Olsson et al., 2018), although the latter study reported significantly more sows requiring farrowing assistance when TC was imposed.

Benefits of reducing confinement pre-farrowing: TC could be improved by allowing sows to nest-build which would not only reduce their stress levels but also has beneficial effects on maternal behaviours by promoting passivity during farrowing (so safe udder access for piglets) and having an impact on suckling success for piglets, reflected in their IgG levels in studies comparing crated sows and sows given plentiful nesting material and space (for review (Yun and Valros, 2015)). One study found an impact on piglet weight and blood glucose when the crates remained open for farrowing (Nowland et al., 2019). There are reports of a higher proportion of dead piglets having empty stomachs when sows were confined only on completion of farrowing compared to both no crating or confinement from 3d prior to farrowing (Hales et al., 2015), suggesting disturbance of the sows may be influencing suckling. But large litter size may be one of the most significant barriers to removing confinement around farrowing. This is supported by a study that left a basic TC open for nesting and farrowing and saw a 16 percentage point difference in piglet mortality with a litter size average of 19 piglets (Yun et al., 2019).

Impacts of confinement during farrowing and early lactation: Given that the immediate post-farrowing period is characterised by reduced posture changes in sows it could be assumed that this will be the least impactful period to confine the sow and the critical period for risks to piglet survival, so most beneficial for piglets. Initially piglets want and need to lie close to the sow, suckle vital colostrum, gain strength and warmth and establish a teat order. Even if sows are reasonably passive, rolling behaviour has been observed to cause non-fatal and fatal crushes in non-confined sows in open pens (Damm et al., 2005). There are practical advantages for farm staff of this period of inactivity as it allows management procedures and piglet survival activities to be carried out safely. By day 3 sows will start to become more restless.

Impacts of confinement during mid-to-late lactation: Under natural conditions sows would start to leave the nest site around day 3 to forage and drink. As early as day 6 post-farrowing sows are reported to reintegrate with their herd and their piglets are expected to follow (Jensen and Redbo, 1987). Whilst sows may not be motivated by the need to forage for food and drink under indoor conditions (where these needs are already met), the removal of confinement and the associated larger space may allow the expression of motivated behaviour such as exploratory behaviour, as well as opportunities for sows to interact more with their piglets. There are mixed reports of this happening in temporary crating systems with some seeing an increase in activity and others not (reviewed - (Wackermannova et al., 2017)). It is likely that a combination of factors will impact on how much exploratory behaviour is seen at this time, including the provision of enrichment, the sow's metabolic status and the space available to increase activity.

Benefits of reduced confinement during lactation: More sow-piglet interactions are considered a positive attribute of reducing confinement. Allowing sows and piglets to freely make nose contact may improve mother–young relationships and piglets' development, possibly benefiting animal welfare and productivity (Ocepek and Andersen, 2018). Although the quantity of space available to piglets has not changed when sows are released, the changed configuration of the space may give different behavioural possibilities, and the possibility for less restricted interaction with the sow may beneficially change their social environment, since time spent playing is increased in the period following TC opening at d3 or d5 when compared to crates (Singh et al., 2017; Loftus et al., 2020). Level of activity may also be increased in later lactation (d18 and 25) in TC conditions compared to crates (Höbel et al., 2018) but this has not always been observed (Goumon et al., 2018). Later in lactation, research suggests that confinement leads to chronic stress. Three studies (Cronin et al., 1991; Jarvis et al., 2006; Yin et al., 2016) all found higher plasma cortisol levels in crated sows compared with sows housed in pens only at the end of lactation (d28, 29, and 35 pp, respectively). This may reflect the parent-offspring conflict, whereby sows are motivated to wean their piglets, but have limited control over the contacts with their litter (Drake et al., 2007). Therefore, temporary confinement only around the first week of lactation should avoid this chronic stress.

Piglet performance: Opening the crate may increase the space available around the udder, thus giving better access to the teats (Pedersen et al., 2011). This may result in less fighting for teats, fewer associated lesions in face and joints and may also contribute to more stable teat order. Kinane et al. (2021) noted that piglets in a TC system were observed more often at the udder than those in a farrowing crate system. These authors also reported increased weaning weights compared to piglets from crated sows and saw this advantage follow through to finishing. Two studies have reported a positive effect of crate opening on weight gain of piglets at weaning (Chidgey et al., 2015; Nowland et al., 2019; Kinane et al., 2021). Most of the other studies (from Table 1 and referenced elsewhere in the REA) have reported no change. It is likely that other factors influence growth rate, including enrichment provision (Oostindjer et al., 2010) and play behaviour (there is a link between growth and play (Brown et al., 2015). Evidence of long-term performance enhancements are lacking and warrant further investigation.

Physical impacts of confinement: Reducing confinement should reduce the risk of injuries from pen fittings. Several studies have investigated the effect of crate opening on the prevalence of body lesions in sows (Lambertz et al., 2015; Singh et al., 2017; Heidinger et al., 2018; Maschat et al., 2020; Ceballos et al., 2021). Maschat et al. (2020), who analysed the effect of five different types of temporary crating pens and the time of confinement removal after farrowing (zero confinement, on d3, 4 or 6 pp) on 24 different injuries (e.g. lameness, shoulder lesion, teat lesions, neck injuries) on weeks 1, 3 and 4 pp. Crate opening on d6 post farrowing led to more back and teat lesions than zero confinement or crate opening on d3. They also showed that different TC pen designs may have different effects on body lesions. Such variability in the risk of fixtures, fittings and flooring causing damage could be seen in any farrowing facility, however, specific to TCs was the potential for the fixtures that held the crate in place when closed being a source of injury once open.

5.2.2. Summary on pen design and welfare

- The majority of pen designs consist of compromises and few if any meet all the biological specification criteria that would maximise welfare. There is a lack of information on pen details described in publications. This makes it difficult to compare the pens and to provide specific recommendations. Details of the pens determine success at meeting biological needs as they interact with the sow, piglets and stock people.

- Confinement of sows in crates impacts welfare but can protect piglets from crushing, especially when there are large litters that have not been equalised and when pen size and limited provision of safe-zones means the sow and piglets are sharing the same space.

- Confinement during nest-building has the most negative effects for sow welfare. Crating during nesting and/or farrowing has negative impacts on farrowing duration. Confinement in the early post-farrowing period (i.e. 0-4 days) is the least detrimental period to confine the sow and the most beneficial period to protect the piglets.

- Reducing the confinement period can mitigate welfare challenges without compromising piglet survival. Allowing sows to be loose upon arrival in the farrowing crates reduces the acute stress response of crating. Developing protocols to reduce confinement and protect piglets is important. Investigating better ways to provide for nest-building behaviour is needed.

- Pen design will impact on pig behaviour, piglet mortality and welfare, but also work quality and safety and the quality of the human-animal relationship.

- Little attention has been given to overall room design and its impact on welfare, but the layout and number of pens in the room are likely to influence animal and human behaviour.

5.3. Stockperson needs and farrowing systems

Management is just as critical, if not more so, than pen design in making loose systems successful. That was the message at a recent workshop on Freedom in Farrowing and Lactation (FFL21)[5] where the theme was 'Overcoming barriers, facilitating change'. Throughout the workshop, discussion came back to aspects of management, including feeding, daily routines, health management, timing of measures such as confinement and handling of sows. Routines in farrowing crates are well established and fairly generic but the variety of alternative systems means that the same system structure/pen design and accompanying husbandry protocol may work well for some but not at all for others.

5.3.1. What to consider when designing and managing alternative systems

Stockperson safety and time management

Safety of staff is a high priority in any workplace. There are valid concerns when sows and staff share the same space. There are a number of specific features of a system that will impact on staff safety and time management. Some have been formally researched, others are reported from the grey literature including farmer testimonials at workshops, case studies and in interviews:

- Wall height:
  - Too low and sows can climb/jump and the sense of enclosure required to promote correct farrowing location (see Table 2) in the nest is reduced
  - Too high and it is difficult for staff to inspect pigs, troughs, escape easily and there is evidence that high walls can increase the fearfulness in piglets (Hayes et al., 2021b) and potentially the maternal defensiveness of the nest in sows.
  - Optimum? In trials by Görtz and colleagues (presented at FFL21 (Gortz et al., 2021)) working with five different free farrowing and temporary crating designs they trialled heights of 0.90m and 1.0m and recommended a minimum height of 1.00m for walls that the sow has access to, below this and there were issues with sows climbing. However other farms operate well with 0.90m but this would be the minimum. Visual aids from outside of the pen are also recommended, such as automated opening of creep lids in a farrowing room allowing quick inspection during checks without piglets being fearful of sudden opening causing them to run out into the pen.
- Ability to separate staff from the sow:
  - Methods include temporary crating, lockable feeding stalls, gates or walls between different areas such as locking the sow in the dunging passage (e.g. SowComfort Pen).
  - Crate opening and closing equipment needs to be simple, ergonomic, and not sensitive to the strength of the worker. Ideally it would only require use of one hand and the process of starting to shut the sow in the crate could be reached from outside the pen.
- Ability to separate piglets from sow:
  - A large, heated creep with access from the service passageway is something very important for ease of handling, staff safety but also piglet safety as it reduces the need to enter the pen to collect piglets. Farmer testimonials and articles in popular press mention this creep space as fundamental. Piglets will want to lie near the sow for the first 12-24h in order to gain access to a teat, establish a teat order and gain warmth from the radiant heat source of the udder (Vasdal et al., 2010). This period will be extended when there are large litters and teat space is limited (Baxter et al., 2020). Lockable creep fronts prevent piglet escape once gathered and can aid with creep training and tasks like split suckling.
- Easy entry and exit points
  - In their evaluation of five alternative systems Görtz et al. (2021) favoured systems that had a separate entry points into the pen rather than having to access through a feeder or across a

[5] Virtual Workshop "Freedom in Farrowing and Lactation": Overcoming barriers, facilitating change: August 12th and 13th, 2021

creep. Having the ability to move sows in from multiple points can be useful but also adds complexity and therefore costs to any design. As does additional walkways between pens (i.e. so that you can access from the back and the front); these would allow inspection of feeders and drinkers if not accessed off a central passageway and would avoid entry into the pen which is beneficial for safety, labour and biosecurity. All these elements add money but could be wise investments for success.

- Pen hygiene and biosecurity
  - When sows are not fixed in one place they have the ability to choose where to defecate. Poor pen hygiene impacts on animal health but also time management if the flooring and dung removal system does not facilitate clean pens. Part solid flooring is important for welfare as it allows greater provision of suitable substrate. It also reduces the amount of exposure animals have to the slurry pits beneath slatted flooring so has an impact on air quality.
- Room design and pen number per room.
  - Much attention has been given to the pen design and specific features required to optimise performance and meet biological needs (Baxter et al., 2011). There has been little attention given to the room design as a whole regarding ease of management and impacts on animal welfare. Pen positioning within the room, access around the pens and number of pens in a room can have a considerable impact on success of systems. When a Danish farmer was asked for their recommendations regarding how many pens should be in one room, they replied no more than two rows of pens per room and no more than 24 pens in a room. Why?

    "The sows are calm and quiet; the staff can perform their routines efficiently and move on to the next batch. Instead of five sections of 96 pens we have 20 sections of 24 pens so four sections for each batch. We can wean twice a week, start washing and cleaning a room without having to wait for more empty rooms. There is no disturbance, it is a comfortable place to work for staff and for pigs and there's fire safety and biosecurity" (Krogsgaard, FFL21[6]).

    The scientific evidence to support this observation relates to the social contagion effect, whereby pigs will react to each other's positive and negative experiences (Reimert et al., 2013).
  - Entrance and exit ways into the farrowing house may have hazards or 'hot spots' that could impact ease of movement of animals and therefore have impacts for both animal and staff welfare. For example, if entry to pens involves walking towards a blind alley a sow will not be keen to go down it – the last pen in a room could be a 'problem pen' not necessarily a 'problem sow'. Pigs are not particularly visual animals, they have wide monocular vision but are not good at short-range vision, so sudden changes in lighting that show up on the floor could cause a sow to freeze (Dalmau et al., 2009). Natural lighting in buildings is considered beneficial for staff, animals and is looked upon favourably by consumers, however placement of windows and the direction of sunlight may have unintended impacts on things like moving animals through buildings. Pigs may perceive shadows and shards of light as changes in floor surface. These are also problems in conventional farrowing houses, but they affect move-in times and will influence the relationship staff have with that sow which can then impact on performance and ease of management throughout lactation.
- Retrofitting barns may seem cost-effective (and sometimes the only choice) but it could be a false economy if the space is sub-optimal for the choice of pen design and for establishing efficient day-to-day working routines.
- Other aspects that are rarely described but increasingly important are ergonomics of fixtures and fittings. Swedish studies have looked into the ergonomics of pen design (Olsson et al., 2010), specifically in relation to muscoskeletal problems associated with mucking out and handling of piglets. They found a great deal of variability in how different pen designs affected working conditions and concluded details were important to successful working routines. For example, the gate locking mechanism and how easy it was to use influences whether workers leant over pens to scrape muck or jumped over pens. Level of pen hygiene is important and details within

[6] Virtual Workshop "Freedom in Farrowing and Lactation": Overcoming barriers, facilitating change: August 12th and 13th, 2021

the pen can influence dunging behaviour of sows and piglets (Andersen and Pedersen, 2011; Andersen et al., 2020).

System differences

There have been two major projects in the last 10 years examining ease of management in alternative farrowing systems (Pro-SAU, Austria (Heidinger et al., 2018) and SEGES, Denmark (Hansen, 2018)). Both principally examined temporary crating systems with Pro-SAU examining the length of confinement period as well as manageability and SEGES focussing on ease of management. SEGES built a showroom on a commercial farm with 1000 sows. Manufacturers of 10 systems installed six of their pen-type in the showroom (60 farrowings for each design). The same farm staff ran them and scored them on:

- Transfer of sows from the gestation to farrowing and back at weaning,
- Offering nest-building material,
- Closing and opening the crate if operating temporary confinement,
- Obstetric assistance
- Removing placenta and dead piglets,
- Cross-fostering,
- Checking trough hygiene,
- Cleaning the trough,
- Mucking out the pen,
- Health checks
- Catching piglets
- Treatments of sows and piglets
- Moving piglets and sows out of farrowing accommodation,
- Washing the farrowing accommodation,
- Disinfection of the farrowing accommodation

The systems were all temporary crating apart from one (Søren). Five had partly solid floors and five had fully slatted floors. They ranged in total pen size from $5m^2$ to $6.9m^2$. Nest building material (straw, jute sack) was supplied daily from transfer until farrowing. In pens with an option to confine (9/10), the sows were confined approximately three days before expected farrowing and released approximately five days after farrowing. They developed a star rating to score each system against the above tasks: ****/***=very good/good and **/* = average/poor (Figure 2). The work concluded that none of the brands were rated "good" or "very good" in all parameters, but several of them achieved satisfactory results in several parameters. They also pointed out the importance of pig producers visiting farms where the pens in question are used in large-scale production. In the Pro-SAU project all systems tested were temporary crating – 3 Austrian designs (Kink, Stewa/Wing and Trapez) with $5.5m^2$ footprints, the SWAP ($6m^2$) from Denmark and Pro-Dromi® ($7.4m^2$) from The Netherlands. They tested the pen-type and the effects of confinement period on workload. They found that confinement period had little effect on additional working time compared to a conventional pen with permanent confinement (1.25-1.33 additional hours per sow per year from zero-confinement to confining 1 day before to 4 days after farrowing respectively). However, pen-type was highly varied ranging from 0.18 to 3.74 additional hours per sow per year, with the larger pen type adding the most additional time.

	Big D	Bopil	FUNKI	Vissing	Vereijken	Søren	STEWA	Midland	VSP/ KU	Jyden
Transfer	*	***	****	****	**	****	***	****	****	****
Gate	**	**	****	****	**	****	****	**	***	****
Dimension	**	**	***	***	***	**	*	*	***	***
Obstetric aid	**	**	***	****	*	**	****	****	**	****
Injury sow	**	***	**	*	*	***	***	*	***	**
Injury pig	*	*	**	**	**	*	**	**	*	*
Feed sow	***	****	****	****	****	***	***	****	***	****
Feed pig	****	****	****	****	****	***	***	***	***	***
Space creep	***	***	***	***	***	**	***	**	****	***
Supervision	**	***	**	**	**	**	**	**	**	***
Use of creep	*	***	***	***	***	****	***	****	***	***
Wean sow	**	***	****	****	***	****	***	***	****	***
Wean pig	***	***	****	***	***	****	***	**	****	**
Safety										
Sow confin.	***	***	****	****	***	-	***	**	**	***
So loose	*	****	**	****	**	*	***	**	**	**
Hygiene	***	**	****	****	**	****	****	****	*	*
Cleanliness	***	***	****	****	***	****	***	***	**	***

1) ****=very good; ***=good; **=average; and *=poor

Figure 2. Evaluation of 10 pens at the SEGES showroom (Hansen, 2018). Excerpt from the final report. 9 pens operated temporary confinement and 1 was zero-confinement (Søren).

Human-Animal Relationship (HAR)

Time management and stockperson safety will also be influenced by sow behaviour. Sows show individual behaviour and this needs to be recognised and handled in free lactation and free farrowing. Breeding may help at the population level, but there will still be individual differences. Developing a positive human-animal relationship is important, not only for animal welfare but also productivity – there is evidence of links between negative HAR and number of piglets per sow per year and that a positive HAR results in better growth and a lower level of stillbirths (reviewed in (Coleman and Hemsworth, 2014). Many scientific papers show that animals can develop neutral or positive perceptions of human beings if proper actions are taken (e.g., see review (Hemsworth, 2007)). Repeated gentle contacts induce a decreased fear of humans and even an increased approach towards humans (Tallet et al., 2018). Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a). Supporting the scientific evidence are reports by farmers about success factors for working with loose housed sows and the importance of staff attitude towards the sows and their empathy towards them and the rewarding aspect of working with loose sows (Anneberg and Sorensen, 2020).

In a case study of Ten Have Farm[7] in The Netherlands, the manager stated *“the majority see a better way of raising pigs as a very good improvement for their job……… Our people are using more time to observe the animal behaviour to prevent problems.”*

Also emphasised by farmers sharing success stories was the importance of having *‘Strict procedures in place from the simplest of tasks to the more complex’*. This is to make sure there’s minimal disturbance, particularly around new mothers and litters so that the sows are good mothers, reducing requirements for intervention. It is also important because not all farms will have a highly skilled and engaged work force. Staff could be transient and require detailed instructions. A more predictable system of management, consisting of a combination of specific routines, is important around the time of farrowing (Rosvold et al., 2017).

[7] Farming pigs and future proofing for a crate-free era

Stockperson training and attitude

There are a growing number of experienced people who work with non-confined sows during farrowing and lactation, including those who manage outdoor systems and those who have adopted indoor free farrowing. Learning from those experienced in day-to-day management of these systems is seen as an important factor in encouraging successful adoption of alternative systems.

There is also evidence from a Danish study (Anneberg and Sorensen, 2020) to identify the motivations of farmers to make changes to enhance welfare. Researchers interviewed 17 farm owners and farm workers from seven large commercial farms. They showed that motivations were much higher if they were able to find others to do it with and share experiences along the way. Networks and participatory experiences, either in the form of 'stable schools' or their own established special networks, were highlighted as something that positively supported change and generated innovation. These authors also cite that the feeling of control for staff and the feeling of being consulted on projects was important to them and the amount they then felt connected to the project and engaged with it. Farm workers liked the idea of being early adopters and involved in innovation and having an influence in decisions. Not all farm workers felt like this though. However, consulting the staff in aspects of pen design that affect their day-to-day working conditions makes sense whether they are engaged or not. Approaching changes to free farrowing and/or free lactation housing with an open-mind and understanding that there may need to be adaptability in established routines for staff and animals are important factors.

5.3.2. Impact of staff and sow experience on performance

There is evidence of a learning curve when new systems are installed on farms, and this has an impact on performance. Staff experience is also a factor. In a study where two farms ran the PigSAFE system and conventional farrowing crates on their respective sites there were site differences in how well the systems performed (Figure 3). Site 1 returned live-born mortality (%) under 9% for both crates and PigSAFE, on Site 2 mortality in PigSAFE was numerically higher than crates. Although this was not statistically significant and there was high variability it demonstrates there can be site differences with the same systems. The farmer on Site 1 had come from managing outdoor sows, thus had good experience with loose sows. The farmer on site 2 had only ever worked with sows in farrowing crates. On closer inspection of the data there were batch effects that showed an improvement in piglets survival as the Site 1 farmer learned how to manage the system (Baxter and Edwards, 2021).

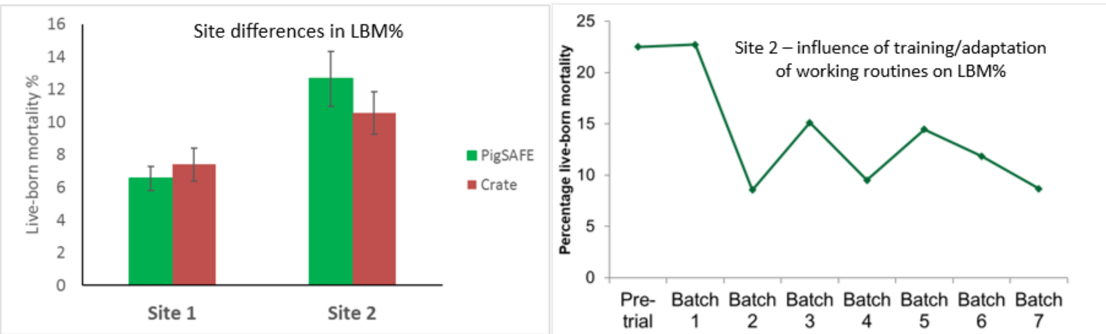


Figure 3. Live-born mortality on two sites operating crates and loose-housing- effects of farmer experience (left) and training (right) on improvements in performance. Full results at Baxter & Edwards, 2021.

Similar results were shown by farmers in a Norwegian commercial uptake trial of the SowComfort pen (reported in (Andersen and Ocepek, 2020)). Liveborn mortality improved by 3% over 5 batches and remained consistent once routines had been established and farmers had learnt the system. In the survey of Danish farmers (Anneberg and Sorensen, 2020) a number of employees mention how the first year was chaotic. It's a chaos they come back to (during the interviews): *'A year ago,* *everyone was new, the previous employees were no longer here, only one had experience - but not about loose sows in the farrowing unit. The owner's word for it 'We had no history'.*

It is not only the staff who have to get used to a system. There have been studies showing that sows that can farrow in the same farrowing environment from 1st to 2nd parity do better than those moving between systems (King et al., 2018, 2019a). This is particularly important as farmers think about transitioning to new systems. They may want to try a few pens and pigs and staff will be swapping between crates and alternatives. The results from King et al. (2018, 2019a) provide the first scientific evidence of something that farmers suspect might be influencing performance. In a Case Study on Dutch farm 'Ten Have' the farm manager noted problems with sows swapping between crates and Pro Dromi® pens. They noted that sometimes, when gilts experienced Pro Dromi® for the first litter, they refused to enter a crate for their next. Consequently, they had to be moved or they stopped eating. They think it likely affected performance but did not formally study it.

5.3.3. Summary on design and management

Maximising performance in the farrowing house does require skilled labour, particularly given the increasing number of interventions needed to deal with large litters, but it can be argued farrowing crates are less sensitive to the quality of the stockperson and the quality of maternal behaviour. Farrowing systems that give the sow greater freedom of movement will constitute a big change for staff experienced with established protocols in crates. Some procedures must be managed differently and will require greater attention to animal behaviour (including developing a positive human-animal relationship) in order to carry out routines safely and time management will be dependent on the specific system and design features that aid working routines.

- The design details of each pen, the quality of the fixtures and fittings, the way in which the pen is orientated in the farrowing rooms and the number of pen places in each farrowing room are all likely to affect manageability.
- The human-animal relationship is a key component in managing loose sows and their litters. Encouraging positive interactions before farrowing could aid manageability after farrowing. Pen design/system choice influence the quality of the HAR.
- Staff motivation and attitude should be considered, and motivating factors include early involvement in projects, dialogue, networking with other farms and training.
- The best solution for farrowing management could be to make the sow do most of the job of taking care of her piglets herself. It is in the farmer's interest to reduce workload, and it is also in the sow's interest to have as little human disturbance as possible, with any human intervention requiring a positive HAR that needs to be a part of the everyday routine for everyone that works on the farm. Designing pens to increase working 'with the sow' not 'against her' (i.e. avoiding potential 'hotspots' that could cause disruption of the HAR).
- Consistency is key: Staff and sow experience influences performance.

5.4. Economic and environmental considerations of farrowing systems

Economics

Investing in new farrowing accommodation will require budgeting for a number of potential costs. These costs will depend on which farrowing system you choose to adopt. Outdoor and certain group housing or multi-suckle systems are generally regarded as low-cost alternatives, whereas individual pens with specific pen features are more expensive. However, costs of any farrowing system are not only dependent on capital investment but also on performance and efficiency (Guy et al., 2012). The major areas in which costs of alternative systems may differ from a crate system are:

- Capital costs of pen structure
- Building space allowance
- Straw bedding provision
- Piglet mortality
- Labour requirements

The main costs come from the increased space requirements for most alternative systems. AHDB Pork have recently completed a comprehensive economic evaluation of alternative farrowing and lactation systems for the UK industry[8] using established costings models developed by InterPig. They concluded:

"Based on the evidence currently available, when taking account of likely changes to physical performance and costings, we expect the cost of production for GB indoor herds installing alternative farrowing systems to increase by 3-8p/kg deadweight depending on the chosen pen design's footprint and the mortality achieved. Even for those producers who might achieve comparable pre-weaning mortality levels, costs are likely to rise by 3-5p/kg deadweight."

Previous modelling exercises by Guy et al. (2012) looked at different cost-neutral or profit-making scenarios. These included modelling improvements in weaning weight, which has since been demonstrated by a number of studies looking at performance in alternative systems (Pedersen et al., 2011; Chidgey et al., 2015; Nowland et al., 2019; Baxter and Edwards, 2021; Kinane et al., 2021). Few studies have followed piglets through to finishing to determine if there is an advantage in days to slaughter and ADG. A recent study did do this and found significant differences in litters from sows that were loose in lactation (Kinane et al., 2021). These authors did keep litters intact throughout rearing and finishing. Other benefits that could offset the costs but are as yet not widely reported in the literature include rebreeding efficiency with increases in subsequent litter size after farrowing in straw pens (King et al., 2019a). As alternative systems are more costly these performance advantages are important to help pay back the capital costs and cost of production, especially if a price premium cannot be achieved. RSPCA Assured are currently the only UK based labelling scheme offering a premium for pigs following their standards which include no use of crates and other stipulations throughout the production chain.

Environmental impacts

Data are lacking on the environmental impacts of alternative farrowing systems. Projects are being undertaken to look at the emissions of different systems (e.g. SowZero – DK), until these data are available modelling exercises and predictions are proposed to discuss potential impacts.

Methodology: To estimate environmental impact, SRUC's Agrecalc tool (www.agrecalc.com) (Agricultural Resource Efficiency Calculator) was used to undertake the cradle to gate assessments. Cradle to gate is an assessment of a partial product life cycle from resource extraction (cradle) to the gate (i.e. the farm gate).

[8] https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf

Agrecalc Tier 2 is certified to PAS 2050:2011[9] standards by approved verifier Lucideon, providing assurance that the GHG emissions being reported are calculated in a consistent way across the industry. PAS 2050 was developed by the British Standards Institution (BSI) in response to broad community and industry desire for a consistent method for assessing the life cycle GHG emissions of goods and services. It provides a common basis for GHG emission quantification that informs and enables meaningful GHG emission reduction programmes.

The Agrecalc Tier 2 calculations follows the GHG emissions methodology published in the Intergovernmental Panel on Climate Change (IPCC) and FAO GLEAM methodology for pigs and poultry (http://www.fao.org/gleam/en/). The Tier 2 methodology seeks to define livestock productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane and nitrous oxide production. Modules within Agrecalc were used to calculate emissions for the individual feed ingredients, based on figures from Feed Print 2015[10] and standard mill energy use figures provided by SACC. Further details of the relevant methodology used in Agrecalc are included as follows.

Table 3 – Agrecalc data requirement - Tier 2

Category	Data
Livestock number and weight	Average livestock number and weight by life stage
Sales, purchases and deaths	Number and weight of livestock bought, sold and, deaths by life stage, KO %
Feed intake	Calculated feed intake per head by life stage
Breeding	Number of litters per sow per year, number of piglets born and weaned per sow.
Performance	Daily liveweight gain by growth stage
Manures	System and whether exported
Feed embedded emissions	Composition of feeds by ration, Feedprint GHG emissions per ingredient combined and standard SAC energy and transport emissions
Feed quantities fed	Quantities fed by ration type and life stage
Feed composition	Recorded Crude Protein, Digestibility, calculated Energy (DE)
Energy use	Electricity, heat, red diesel and renewables

Data

For calculating embedded feed emissions and diet nutritional specification standard rations provided by SAC Consulting were used.
For the direct emissions on-farm for the baseline scenarios (indoor crate and outdoor) AHDB Pork data was used;

- quantities of diets fed by stage (kg) (AHDB Pork)
- number of livestock purchased, born and sold by growth stage (AHDB Pork),
- number of deaths and mortality by growth stage (AHDB Pork)
- opening and closing livestock weights (liveweight) at each stage and slaughter (AHDB Pork),
- kill out % (AHDB Pork)

SAC Consulting provided;

- feed composition (SACC),
- crude protein (CP) and Digestibility (%), gross energy (GE) and apparent metabolisable energy (DE) (MJ/kg DM) of the feed.

Comparisons

[9] http://shop.bsigroup.com/forms/PASs/PAS-2050-Guide/

[10] Feed Print 2015 - http://www.blonkconsultants.nl/wp-content/uploads/2016/06/Animal-products.pdf

Using Agrecalc SAC Consulting calculated the Global warming potential expressed in kg CO_2e per kg liveweight (lwt) and deadweight (dwt) of pig-meat (net of purchase weight) following an IPCC methodology for Tier 2. Emissions are expressed on a net sales basis as embedded emissions associated with any purchased livestock were not included.

GHG emissions were compared without land use change (LUC) impacts.

Results

For this REA we used the Agrecalc model to look at emissions in Indoor conventional crate and Outdoor commercial production based on database inputs for these systems provided by AHDB Pork. Creep usage in the pre-weaning period was the only value not provided by AHDB Pork, as it is rarely recorded pre-weaning and highly variable. It was assumed that farmers start introducing creep in the last week of lactation (although it is noted that some farms may be introducing crumb earlier, especially for large litters). We sought intake data from the scientific literature on individual creep feed intake in the last week of lactation (Bruininx et al., 2004) and extrapolated. We then modelled two different mortality levels from the baseline average indoor live-born mortality set at 12.2%. These were 14% (S1) and 18% (S2) and were based on scenarios AHDB Pork had set in their economic evaluation. We then modelled further scenarios S3; increased straw use for behavioural enrichment for nesting and enrichment for lactation of +5kg per sow per litter and S4; increased weight of piglets at weaning from a free farrowing system; assumed to be +374g to 7.77kg per piglet leading to a reduction of 1.6 days in finishing time and associated energy and feed savings.

The results are detailed in the following table which illustrates that any increase in farrowing mortality and straw use will increase carbon emissions per kg dwt but that these changes are minor at the finished pig level. Where alternative systems lead to larger weaned piglet size then reductions in finishing time would lead to a small reduction in per kg dwt carbon emissions (1%).

Table 4. Output of AgreCalc modelling of emissions for baseline Indoor and Outdoor breeding herd (green header) and Scenarios 1-4 (orange header) of potential impacts of alternative farrowing systems (S1 = higher mortality 14%, S2 = higher mortality 18%, S3 = Extra straw enrichment, S4 = Higher weaning weights, quicker finishing).

		BASELINE			BASELINE			Scenario 1	Scenario 2	Scenario 3	Scenario 4
		1 - Indoor - Breeder - Baseline 12.2% mort	2 - Indoor - Finisher - Baseline	INDOOR COMBINED - Breeder - Finisher	3 - Outdoor - Breeder - Baseline	4 - Outdoor - Finisher - Baseline	OUTDOOR COMBINED - Breeder - Finisher	5 - Indoor - Breeder - S1 - 14% mort	6 - Indoor - Breeder - S2 - 18% mort	7 - Indoor - Breeder - S3 - ex straw 12.2%m	8 - Indoor - Finisher - S4 - Quicker finish 12.2%m
CARBON DIOXIDE	(kg CO2e)	708,086	2,562,629	3,270,715	991,559	3,640,882	4,632,441	708,349	708,932	709,993	2,535,568
METHANE	(kg CO2e)	106,880	994,586	1,101,466	110,986	424,531	535,517	106,557	105,837	106,880	980,447
NITROUS OXIDE	(kg CO2e)	150,281	472,461	622,742	332,664	1,158,626	1,491,290	149,473	147,670	150,281	466,509
TOTAL	(kg CO2e)	965,247	4,029,676	4,994,923	1,435,209	5,224,039	6,659,248	964,379	962,439	967,154	3,982,524
Output	(kg dwt)	123,734	1,324,975	1,448,709	158,074	1,758,362	1,916,436	121,674	117,179	123,734	1,321,546
CARBON DIOXIDE	(kg CO2e/kg dwt)	5.72	1.93	2.26	6.27	2.07	2.42	5.82	6.05	5.74	1.92
METHANE	(kg CO2e/kg dwt)	0.86	0.75	0.76	0.70	0.24	0.28	0.88	0.90	0.86	0.74
NITROUS OXIDE	(kg CO2e/kg dwt)	1.21	0.36	0.43	2.10	0.66	0.78	1.23	1.26	1.22	0.35
TOTAL	(kg CO2e/kg dwt)	**7.80**	**3.04**	**3.45**	**9.08**	**2.97**	**3.47**	**7.93**	**8.21**	**7.82**	**3.01**
Diff fromm baseline	*(kg CO2e/kg dwt)*							*0.13*	*0.41*	*0.02*	*-0.03*
	(%)							*1.7%*	*5.3%*	*0.3%*	*-1.0%*
CARBON DIOXIDE	(%)	73%	64%	65%	69%	70%	70%	73%	74%	73%	64%
METHANE	(%)	11%	25%	22%	8%	8%	8%	11%	11%	11%	25%
NITROUS OXIDE	(%)	16%	12%	12%	23%	22%	22%	15%	15%	16%	12%
TOTAL	(%)	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Per piglet produced	(kg CO2e/hd)	55.20	248.65	303.86	64.79	254.46	324.37	56.33	58.96	55.31	245.74

Table 5: Detail and commentary of output from *AgreCalc modelling of emissions for baseline Indoor and Outdoor breeding herd (green header) and Scenarios 1-4 (orange header) of potential impacts of alternative farrowing systems (S1 = higher mortality 14%, S2 = higher mortality 18%, S3 = Extra straw enrichment, S4 = Higher weaning weights, quicker finishing).*

	BASELINE	**Scenario1**	**Scenario2**	**Scenario3**	**BASELINE**	**Scenario4**
	1 - Indoor - Breeder Finisher - Baseline 12.2% mort	**5 - Indoor - Breeder - S1 - 14% mort**	**6 - Indoor - Breeder - S2 - 18% mort**	**7 - Indoor - Breeder - S3 - Extra straw 12.2%m**	**2 - Indoor - Finisher - Baseline**	**8 - Indoor - Finisher - S4 - Quicker finish 12.2%m**
General		Higher mortality reduces the number of pigs weaned from the same sows; lowering output. All else being equal this increases emissions per kg of output as there is a lower output to divide emissions by.	Higher mortality reduces the number of pigs weaned from the same sows; lowering output. All else being equal this increases emissions per kg of output as there is a lower output to divide emissions by.	Higher straw use - an extra 5kg per sow per lactation.		Piglets from alternative indoor farrowing units arrive 374g heavier at 7.77kg, enabling finishing 1.6 days quicker, leading to lower average nos, lower feed and electricity use.
General	**(kg Co2e/kg dwt)**	**(kg Co2e/kg dwt)**	**(kg Co2e/kg dwt)**	**(kg Co2e/kg dwt)**	**(kg Co2e/kg dwt)**	**(kg Co2e/kg dwt)**
CARBON DIOXIDE	5.72	5.82	6.05	5.74	1.93	1.92
METHANE	0.86	0.88	0.90	0.86	0.75	0.74
NITROUS OXIDE	1.21	1.23	1.26	1.22	0.36	0.35
TOTAL	**7.80**	**7.93**	**8.21**	**7.82**	**3.04**	**3.01**
Diff from baseline (%)		1.67%	5.26%	0.26%		-0.99%
CARBON DIOXIDE						

		Total emissions remain almost unchanged - small savings in lower creep use are offset by rising emissions from carcase disposal. But falling output raises product per kg emissions. Sow feed use (902t) is unchanged, creep feed is reduced but overall quantities used are very low (5.63t reduced to 5.53t) compared to sow feed. Energy and bedding quantities are unchanged but rise on a per kg of piglet produced basis as output falls. Carcass disposal emissions rise but this remains a small source.	Total emissions remain almost unchanged - small savings in lower creep use are offset by rising emissions from carcase disposal. But falling output raises product per kg emissions. Sow feed use (902t) is unchanged, creep feed is reduced but overall quantities used are very low (5.63t reduced to 5.45t) compared to sow feed. Energy and bedding quantities are unchanged but rise on a per kg of piglet produced basis as output falls. Carcass disposal emissions rise but this remains a small source.	Higher embedded carbon emissions of using additional straw for enrichment.		Feed use is reduced by 1.6 days or 45 tonnes to 2,391t, electricity use is reduced by1.6 days or 4,894 kWhr to 259,976 kWhr.
METHANE						
		Total emissions fall due to the lower average nos of piglets alive. But output falls faster leading to higher per unit emissions.	Total emissions fall due to the lower average nos of piglets alive. But output falls faster leading to higher per unit emissions.			Average livestock numbers over a 12-month period are reduced due to the 1.6 days shorter finishing period dropping from 6,704 to 6,616. This leads to lower methane emissions from feed digestion.
NITROUS OXIDE						
		Total emissions fall due to the lower average nos of piglets alive. But output falls faster leading to higher per unit emissions.	Total emissions fall due to the lower average nos of piglets alive. But output falls faster leading to higher per unit emissions.			Shorter time on farm as detailed above leads to lower nitrous oxide emissions from feed

6. Appendices

6.1. Evidence for Farming Initiative (EFI) Draft Evidence Standards

6.1.1. Effectiveness

-ve	**Evidence tends to show a negative effect.** The balance of evidence (including the pooled effect size where available) suggests that the practice has a negative effect, meaning the practice made things worse. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement (number and size of participating entities) in those studies.
0	**No effect.** The balance of evidence (including the pooled effect size where available) suggests that the practice has no effect overall.
+/-	**Evidence tends to show a mixed effect.** Studies show a mixture of effects and the criteria for ‘tends to negative effect’ or ‘tends to positive effect’ are not met.
+	**Evidence tends to show positive effect.** The balance of evidence (including the pooled effect size where available) suggests that the practice has a positive effect. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement in those studies.
++	**Evidence shows consistently positive effect.** The evidence (including the pooled effect size where available) consistently suggests that the practice has a positive effect. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement in those studies.

6.1.2. Cost

£	No new equipment or time constraints over and above existing business as usual (BAU) running costs.
££	May need some additional time for training or experiential learning to establish new practice, but once implemented this rapidly transitions into BAU running costs.
£££	As above, plus new equipment and capital costs for machinery and implements on farm.
££££	Major investment in new infrastructure on farm and/or loss of land utility/land use change that is greater than the normal rotation(s).

6.1.3. Speed of change

Fast	Effective immediately, change within 0-3 months.
Moderate	Effective within 12 months.
Slow	Effective in longer than 12 months.

6.1.4. Strength of evidence

	Very high	High	Moderate	Low	Very low
	●●●●●	●●●●○	●●●○○	●●○○○	●○○○○
Quality of literature	An extensive body of high-quality evidence reviews.	A developing body of high-quality evidence reviews.	Studies of the highest quality (randomised control trial equivalent) OR at least one high-quality evidence review.	Studies using quasi-experimental methods OR at least one moderate-quality evidence review.	High quality observational studies.
Relevance of context	As level 4, but with excellent contextual and Implementation insight drawn from high-quality studies and on-farm practice.	Includes evidence generated in farming and growing businesses with farmers and growers testing the practice.	Evidence generated in farming and growing businesses with the practice applied by professional researchers.	Evidence generated in research centre farming and growing facilities.	Evidence generated through laboratory research.
Overall	We can draw very strong conclusions about impact and be highly confident that the practice does/does not have the effect anticipated. The body of evidence is very diverse and highly credible, with the findings convincing and stable.	We can draw strong conclusions about impact and be confident that the practice does/does not have the effect anticipated. The body of evidence is diverse and credible, with the findings convincing and stable.	We can draw some conclusions about impact and have moderate confidence that the practice does/does not have the effect anticipated. The design of the research allows contextual factors to be controlled for.	We believe that the practice may/may not have the effect anticipated. The body of evidence displays significant shortcomings. There are reasons to think that contextual differences may substantially affect practice outcomes.	The body of evidence displays very significant shortcomings. There are multiple reasons to think that contextual differences may unpredictably and substantially affect practice outcomes.

7. Narrative Summaries

The narrative summaries are presented in order of increasing spatial footprint of the farrowing pen. We have chosen to do this because of the emphasis placed on space when making decisions. Space is undoubtedly important; it is often the starting point when deciding on new building developments, it dictates finances, planning permission, herd size and it impacts on animal welfare and labour demands. Choosing a system with a spatial footprint that maintains the status quo is tempting given it has the least immediate economic impact. However, this results in limited or no improvements in animal welfare and may actually be harmful to performance if the intention is to use the pen for zero-confinement at some point in the future. Figure 4 below is intended to illustrate the relationship between different factors that are likely to be prioritised when making decisions about alternative indoor farrowing and lactation systems.

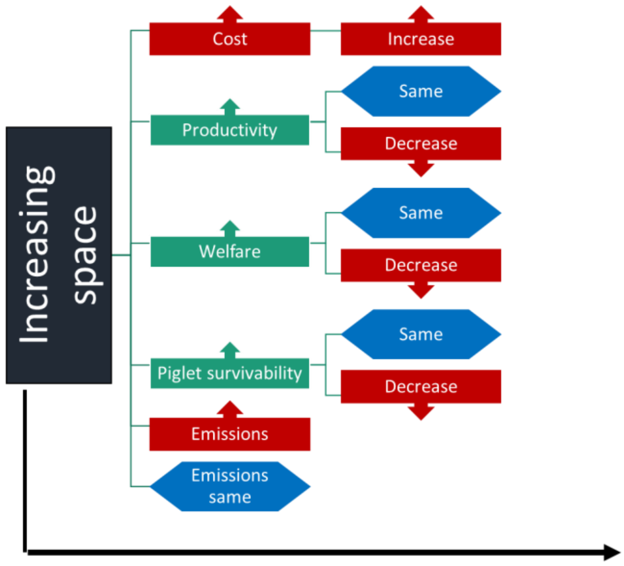


Figure 4. Illustration of proposed relationship between space and important factors informing decisions about choosing an alternative indoor farrowing and lactation system. Red indicates an undesirable increase of decrease in a factor, green represents a desirable outcome and blue represents no change. Please note this is theoretical and data on factors such as emissions are lacking.

Increasing space always increases costs, it can increase productivity (e.g. through easier udder access for piglets and increased weaner weights (Pedersen et al., 2011)), welfare and piglet survivability to a certain point but that can plateau or even decrease if the space becomes too large. For example, if a pen is too large for piglets to maintain optimum contact with the sow and safe zones or if the size of the space prevents good management to assist piglets (e.g. group systems). Other factors are increasingly part of the decision-making process - namely emissions targets. Here it is predicted that emissions will go up as space increases if the slurry surface also increases. It will remain the same if the slurry surface stays the same but the solid floor increases. The lack of empirical data needs to be addressed so more informed decisions can be made about the likely trade-offs between welfare, costs and environment. The narrative summaries are intended to act as a guide to alternative systems to allow informed choices based on the available evidence-base and commercial information where available.

Common factors across systems

There are a number of factors and husbandry routines that are common to all indoor systems, and these are summarised here to avoid repetition within each narrative summary.

- It is assumed that all practices, systems, buildings and utilities (i.e. lighting, ventilation, water supply) adhere to the minimum regulatory requirements for keeping pigs in the UK (Welfare of Farmed Animals (England) Regulations 2007).
- All pen equipment, flooring, fixtures and fittings are built using suitable components.
- Overall period in the farrowing house is from entry into the farrowing area until weaning.
- Typical modern, commercial dam-line genetics are used (i.e. not rare breeds)
- Typical husbandry procedures are practiced, including cross-fostering.
- Any resection of corner teeth and permitted tail-docking is carried out within 3 days.

- No castration, as not practiced in UK production.
- Iron injections are given by day 3 post-farrowing.
- Piglets are considered to be fully sentient from birth.
- It is assumed that husbandry practices are compliant with the legislation, therefore piglets are supplied with minimum enrichment material (e.g. wooden block on chain) and sows are provided with nesting material. Any specifics regarding types of enrichment that might be more typical of certain systems will be noted in the summaries.
- Weaning age averages 26 days (UK average from Cost of production (COP) statistics, InterPig).
- Sows are fed according to recommended standards and are typically fed twice a day in farrowing accommodation, if not on ad libitum post-farrowing.

Staff considerations common to all systems:
There is an increased risk to staff safety when sows are loose, when staff and sows need to 'share' the same space (e.g. when gathering piglets for husbandry purposes). In general walls need to be higher than in conventional crates and this reduces the speed of exit and entry into the sow space, which could constitute a risk if the sow is hyper-responsive to human presence.

Economic predictions:
Where possible information about costs have been estimated using the spreadsheet-based economic simulation model developed by (Guy et al., 2012; Seddon and Edwards, 2012) (available here). It estimates the cost of producing a piglet in different farrowing systems, in comparison to the standard farrowing crate. The user can select their current housing system and an alternative farrowing system for comparison. There are a variety of systems available, but it is not an exhaustive list and therefore some costs cannot be estimated. Once information about the farrowing system is entered, the cost of production in the farrowing sow and gestation sow phase is generated along with the variable and fixed costs for each system combination. Reference values of a typical UK indoor commercial herd were entered from information supplied by AHDB Pork as part of the InterPig Cost of Production database for 2020. The gestation unit (required to calculate full costs of producing a weaner) was selected as straw courts and we chose a hand-feed operation in the farrowing unit.

Economic evaluations of systems are sensitive to performance. For each system we used average performance data (from COP) as reference values throughout, regardless of our assessment of impacts on mortality or weaning weight.

- Guy JH, Cain PJ, Seddon YM, Baxter EM and Edwards SA 2012. Economic evaluation of high welfare indoor farrowing systems for pigs. Animal Welfare 21.
- Seddon, Y.M., Cain, P.J., Guy, J.H. and Edwards, S.A., 2013. Development of a spreadsheet based financial model for pig producers considering high welfare farrowing systems. Livestock Science, 157(1), pp.317-321.

Reference system: Farrowing crate

The reference system for comparison against the alternatives described in the narrative summaries is a conventional farrowing crate, built on a fully slatted pen, above slurry pits. Overall pen area consists of a crate where the sow is confined for farrowing and lactation with adjacent area for piglets that the sow cannot access that is provided with a heat source and solid flooring. Typical floor footprint 3.6-4.3m^2. It is assumed that the common factors listed above are also common to conventional farrowing crates.

7.1. Temporary Crating - Basic

Impact summary

***Temporary Crating Basic** is an alternative farrowing and lactation system built on the same spatial footprint as a conventional farrowing crate (3.6-4.3m^2). The system is installed on fully slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a separate, solid lying area with a heat source. The system is intended to retain all the features of the existing farrowing crate except the crate structure itself can be opened up during lactation to allow the sow to turn around and give easier access to the udder for piglets. This typically happens 4-7 days post-farrowing. Sows are crated on entry to farrowing rooms. Inputs are expected to be compliant with legislation, therefore sows are provided with nesting material (handful of chopped straw or shredded paper in trough or hessian sack tied to front of crate) and piglets are provided with enrichment material (typically shredded paper or wooden blocks on chains).*

Effectiveness		
	Improved piglet survival	0
	Improved sow welfare	+
	Improved piglet welfare	+/-
	Stockperson safety	0
	Hygiene	0
	Ease of management	0
	Other factors	
	Improved weaning weight	+/-
	Potential for price premium	0
Cost		
		££
Speed of change		
		Moderate
Strength of evidence		
	Quality	Moderate
	Context	Moderate
	Overall	Moderate

7.1.1. What is the system?

Temporary Crating – Basic (TC-Basic) is an alternative farrowing and lactation system built on the same spatial footprint as a conventional farrowing crate (3.6-4.3m^2). The system is intended to retain all the features of the existing farrowing crate except the crate structure itself can be opened up during lactation to allow the sow to turnaround.

Example: 360° Farrower

360° Farrower in open (left) and closed (right) position. Image courtesy of M. Farish SRUC.

System components: A swing-side or push-back crate is installed on the same spatial footprint as conventional crates on fully slatted floors. Space available to the sow when in an open position varies depending on the size of the piglet lying area and the dimensions of the crate and how it is fixed when in the open position. Unimpeded turning (i.e. without touching the crate sides) depends on the size of the sow. Crate sides form farrowing rails for piglet protection when open. The system is installed on fully slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a separate lying area (solid) with a heat source. A food trough and drinker for the sow is provided at the front of the crate. A separate drinker is provided for the piglets.

Husbandry: Sows are crated on entry to farrowing rooms. The crate is opened up to allow the sow to turnaround 7 days post-farrowing. Sows and piglets have access to nesting (typically shredded paper or chopped straw or a hessian/burlap sack attached to the front of the crate) and enrichment material.

7.1.2. How effective is it?

The balance of available evidence suggests a mixed effect when it comes to piglet survival in the TC-Basic system with the confinement protocol described. On the whole early piglet survival is similar to that reported in the farrowing crates, however there is evidence in some studies and observations from farmers using these systems of spikes in mortality when the crate is opened up (King et al., 2019b). Improvements can be made in management to reduce this risk (see How can I do it well?). A larger safe-zone for piglets (i.e. creep) would reduce the risk of sows and piglets sharing the same space, however this would require a bigger footprint or reducing the space available to the sow further. By opening up the crate in lactation the sow's welfare is marginally improved as she is able to turn around without obstruction (depending on the size of the sow space provided and the how much the crate fixings open up) with more autonomy over orientation within the pen. Welfare compromises are still apparent because of the close confinement operated prior to this, including confinement during the nest-building phase, known to cause welfare detriments (Baxter et al. 2018). There are indirect consequences for piglet welfare as a result of impaired nest-building behaviour; including evidence in some studies of prolonged duration of farrowing, reduced oxytocin levels and increased risk of activity during farrowing (Oliviero et al., 2010). Due to the size of the pen and the inability to separate out areas into functional zones it is typical/recommended to have a fully slatted floor. Whilst this improves hygiene it limits provision of suitable nest-building material and continued access to suitable enrichment material (i.e. it can fall through the slats). This is similar to typical farrowing crate scenarios so there are no improvements in this regard when using TC-Basic as described. Opportunities for welfare enhancements for the piglets are limited, although there is some evidence of easier udder access when crate bars are removed, which can equate to greater suckling success and higher weaning weights (Pedersen et al., 2011). The potential risk for crushing mortality when the sow is released from the crates means there are welfare compromises and the limited provision of space, enrichment and socialisation are the same as that experienced in farrowing crates. A large evaluation trial run by SEGES documented ease of management for different systems, including a TC-Basic system ('Midland') - (Hansen, 2018). For the category ‘dimensions’ evaluating the space provided for the animals and staff and for categories relating to sow confinement and sow being loose it was given a rating of ‘poor’ and ‘average’ respectively (there were 4 ratings categories: *=poor, **=average, ***good, ****=very good).

Stockperson safety is considered no better or worse than farrowing crates assuming the crate opening and closing procedure allows the stockperson to remain separated from the sow. However evidence from the SEGES trial scored safety as ‘average’ for a TC-Basic system (Hansen, 2018). Fully slatted flooring allows hygienic and labour-efficient conditions, however with no zonation of lying, dunging and feeding areas there is potential for sows to dung in their feeder when the crate is in the open position. Typical pig feeding behaviour involves eating and then turning around from the feeding area to eliminate (Andersen and Pedersen, 2011). In the proposed system this constitutes a risk for fouling the feeder. However, in the SEGES trial a TC-Basic scored ‘very good’ and ‘good’ for hygiene and cleanliness. Evidence for ease of management suggests that there are few differences between this system compared to conventional crates, however specific features of any pen design (and features of the farrowing room as a whole) can aid or hinder ease of management – such as access to piglets from passageway, access for obstetric assistance, orientation of pens within the room, opening mechanism of the crate etc.

7.1.3. Where does it work?

This system is designed for indoor fully slatted sheds and can be retrofitted into existing sheds without compromising size of farrowing batch due to occupying the same footprint as standard crates.

7.1.4. How much does it cost?

Cost of producing a weaner per sow per year was estimated at = £12.93 vs. £12.52 for a conventional system in farrowing houses (£0.42 difference).

7.1.5. How can I do it well?

Improvements can be made to management and inputs to reduce welfare compromise and enhance performance.

System specific:

- Reduce confinement for sow pre-farrowing. Move in sows 4-5 days before their due date and allow them to be loose when they first move in, especially important with gilts.
- Provide plentiful and accessible nest-building material. When crate is closed ensure sow can access material (e.g. fix a hessian sack to crate fittings, replenish substrate frequently).
- Get sows and gilts used to confinement by closing them in at afternoon feeding time and overnight, repeat until 1 day pre-farrowing.
- Leave crate closed from 1 day before expected farrowing and during early lactation to protect piglets. Evidence suggests that shutting sows in during active nest-building could be acutely stressful (Pedersen and Jensen, 2008b) having impacts on farrowing duration (Yun et al., 2015a). Having crates open during farrowing and early lactation risks increased piglet crushing, especially when using hyperprolific genetics (Yun et al., 2019b). The lack of space to avoid crushing piglets and/or to interact with them safely (e.g. grouping behaviour by sow) is suggested as a limiting factor for operating open ((Weber et al., 2009; Yun et al., 2019b).
- Ensure interactions, particularly during opening and closing, are positive. No forced or sudden movements, no loud voices. Suggest encouragement into the crate during confinement training with feed, enrichment. Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a).
- Reduce confinement period post-lactation to maximum 4 days – evidence suggests piglet mortality risk after this period is low (Heidinger et al., 2018).

- Open the crates individually (i.e. when the age of each litter is 4 days), rather than simultaneously as a batch.
- Open crates in the afternoon – evidence for reduced mortality compared to opening all at once in the morning (King et al., 2019b).
- Consider choice of slurry removal system – a scraper system would allow greater provision of nesting materials as there is reduced risk of blockages in slurry removal. This would allow retention of the fully slatted floor required to maintain hygiene.

General advice:

- Engage stock workers in renovation/design/retrofit process.
- Provide staff training to new system.
- Ensure building into which farrowing pens are fitted is optimal for workability, ventilation, lighting, staff safety – e.g. entry and exit points for pigs and staff can influence ease of movement.
- Consider numbers per farrowing room for optimal workability (e.g. so that tasks can be performed in workable batches rather than large numbers all at once) and to reduce a contagion effect of disturbance (i.e. one hyperreactive sow could cause problems throughout the farrowing room).
- Consider orientation within farrowing room to allow easy and safe access from passageways and potential for obstetric assistance if needed.
- Consider fittings in pen and on crate that can provide attachment for point-source enrichment items for piglets and sows for nesting behaviours.
- Ensure suitable support structures are in place under foot (i.e. under the slats) to account for increased traffic in pens as a result of sows moving around more.
- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2018, 2019a).
- Select gilts with good leg strength and agility.
- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline.
- There is consistent evidence that older, high parity sows return higher piglet mortality levels and should be avoided.

7.1.6. How strong is the evidence?

The evidence for performance in these systems is moderate but it is likely more can be gleaned from commercial herds with similar systems in operation willing to share their data. As the system is very similar to a conventional farrowing crate the evidence for welfare compromise is very high. Welfare opportunities are limited in the constraints of the system, however evidence for the benefits of providing nesting materials and enrichment for piglets is high. Evidence for optimising management to improve welfare (i.e. reduced confinement period, best practice for opening times) is moderate but is expected to increase with increased uptake of systems and heightened research activity.

7.1.7. Where can I find further information?

- Different temporary crating systems can be compared at: https://www.freefarrowing.org/farrowing-systems/temporary-crating/
- The SEGES final report evaluating 10 different housing options for loose lactating sows (including Temporary Crating Basic options) from a practical point of view can be found here or via http://svineproduktion.dk/Publikationer
- AHDB Pork have completed an evidence report comparing the impact of alternative farrowing systems, including an economic assessment: https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf
- AHDB Pork's Knowledge Library has video material on temporary crating management: https://ahdb.org.uk/knowledge-library/temporary-confinement-farrowing-systems

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7.2. Temporary Crating +

Impact summary

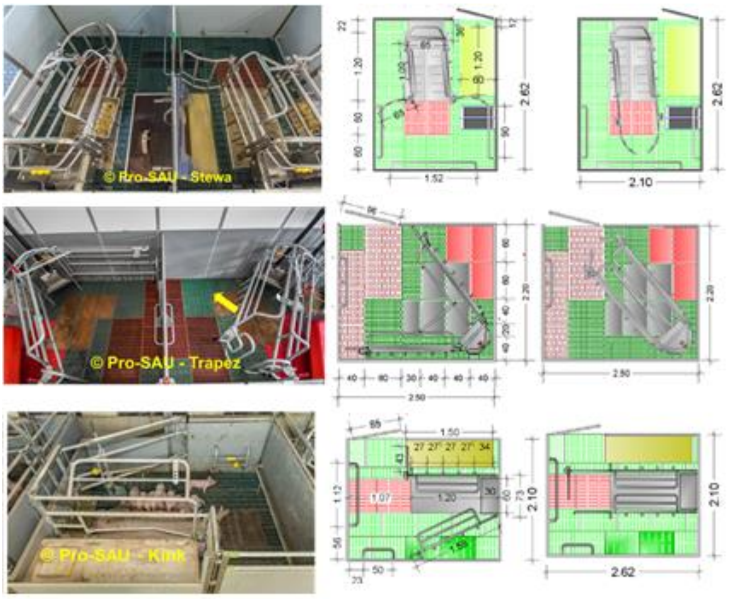
***Temporary Crating +** is an alternative farrowing and lactation system built on a larger footprint to the conventional farrowing crate (5.5-6.0m^2). The system is installed on fully slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a separate, solid lying area with a heat source. The system is intended to retain all the features of the existing farrowing crate except the crate structure itself can be opened up during lactation to allow the sow to turnaround and easier access to the udder for piglets. This typically happens 4 days post-farrowing. Sows are crated 1 day before their farrowing due date. Inputs are expected to be compliant with legislation, therefore sows are provided with nesting material (handful of chopped straw or shredded paper in trough or hessian sack tied to front of crate) and piglets are provided with enrichment material (typically shredded paper or wooden blocks on chains).*

Effectiveness		
	Improved piglet survival	0
	Improved sow welfare	+
	Improved piglet welfare	**+/-**
	Stockperson safety	0
	Hygiene	0
	Ease of management	0
	Other factors	
	Improved weaning weight	+
	Potential for price premium	0
Cost		
		£££
Speed of change		
		Moderate
Strength of evidence		
	Quality	High
	Context	Moderate
	Overall	Moderate

7.2.1. What is the system?

Temporary Crating + (TC+) is an alternative farrowing and lactation system built on a larger spatial footprint than conventional farrowing crate (5.5-6.0m^2). The system is intended to retain all the features of the existing farrowing crate except the crate structure itself can be opened up during lactation to allow the sow to turn around.

Examples: Stewa (Wing), Trapez, Kink, Opti-farrow (VissingAgro), BeFree (Schauer)



Pictures provided courtesy of J. Baumgartner, VetmedUni. Evaluated as part of the Pro-SAU project, Austria

Vissing Agro's OPTI-FARROW.
Picture courtesy of E. M. Baxter.

System components: A swing-side or push-back crate is installed on fully slatted flooring on top of slurry pits. The space available to the sow when in an open position varies depending on the size of the piglet lying area (creep) and the dimensions of the crate and how it is fixed when in the open position. In the examples provided uninterrupted space available to the sow ranged from 2-5m^2 when in the open position. Unimpeded turning is therefore system dependent, as well as dependent on the size of the sow. Crate sides form farrowing rails for piglet protection when open. Low rails are positioned on walls not in contact with the crate. The system is installed on fully slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a separate lying area (solid) with a heat source, often a covered creep situated close to the staff passageway. A food trough and drinker for the sow is provided at the front of the crate. A separate drinker is provided for the piglets.

Husbandry: Sows are loose upon entry to farrowing rooms and then restrained in the crate 1 day before her due date. The crate is opened up after 4 days post-farrowing. Sows and piglets have access to nesting (typically shredded paper or chopped straw or a hessian/burlap sack attached to the front of the crate) and enrichment material.

7.2.2. How effective is it?

The balance of available evidence suggests there is no difference between piglet survival figures in the TC+ system using the confinement protocol described compared to conventional farrowing crates. By allowing the crate to be opened upon entry into the farrowing house until 1d before farrowing and again 4 days into lactation the sow's welfare is moderately improved as she is able to turn around without obstruction (depending on the size of the sow space provided and how much the crate fixings open up) with more autonomy over orientation within the pen and greater freedom of movement during lactation. There is a suggestion from farmers operating these systems that allowing this freedom prior to farrowing is especially beneficial for gilts who are yet to experience close confinement or single housing. It also allows increased ambulation in the lead up to farrowing which is a motivated behaviour in preparation for nest-building (Jensen, 1986).

As described for TC-Basic welfare compromises are still apparent because of the close confinement during the nest-building phase and around farrowing for the sow (Baxter et al. 2018). There are indirect consequences for piglet welfare as a result of impaired nest-building behaviour; including prolonged duration of farrowing reported in some studies, reduced oxytocin levels and increased risk of nest-building activity during farrowing (Oliviero et al., 2010). Limited provision of nest-building materials and the continued access to those materials (which is restricted when confined and on fully slatted flooring) also means there are no improvements compared to the conventional crate. Opportunities for welfare enhancements for the piglets are limited, although there is some evidence of easier udder access when crate bars are removed, which can equate to easier suckling success and higher weaning weights (Pedersen et al., 2011). Greater space provision for piglets could facilitate greater opportunities for locomotory play.

The provision of a covered creep area near to the sow (but with access from a central passageway) offers a protected, thermally comfortable area for the piglets. An attractive creep area for the piglets is also useful for stockpeople who can more easily access the piglets rather than having to get in and catch for husbandry, which therefore reduces negative human-animal interactions and reduces the risk of spreading disease from one pen to another. Stockperson safety is considered no better or worse than farrowing crates but that assumes the crate opening and closing procedure allows the stockperson to keep separated from the sow. Note though that this is very system dependent – there are a variety of systems available that would be categorised under 'TC+' mainly because of their 5.5-6m^2 footprint, but quality and positioning of the fixtures and fittings within the pen and crate opening/closing procedure can have marked effects on functionality (see Pro-SAU report - (Heidinger et al., 2018)) and on piglet, sow and staff safety. For example, in the Trapez pen the crate fastening was a source of injury to piglets after opening due to its positioning in the centre of the pen, whereas the Stewa/Wing operated on a leverage system with the bars able to be secured off the ground leaving no exposed metal work in the flooring. It did, however, reduce the sow's ability for unimpeded turning. More generally the provision of a fully slatted floor allows hygienic and labour-efficient conditions. Although there is no obvious zonation between lying and dunging areas, the greater space compared with TC-Basic gives the sows greater opportunity to orientate away from feeding areas post-feeding.

Evidence for ease of management suggests that there are few differences between TC+ compared to conventional crates, however this is very task and system dependent. As with TC-Basic features both in and out of the pen influence efficiency such as access to piglets from passageway, access for obstetric assistance etc. In a large evaluation of labour efficiency in these systems as part of the Pro-SAU project (Blumauer et al., 2018) staff were asked to assess several tasks for ease. Confinement period (tested day-1 to day + 3 and day +5) had no effect on working time, but the specific system was influential and ranged in additional work time of 0.18-3.74 hours per sow per year compared to crates. Pen detail is influential - for example, the Trapez increased piglet catching time because the piglets hid under the feeder. However, in the SEGES evaluation (Hansen, 2018) the Trapez was actually favoured by farm staff and upon completion of the trial it was chosen for more investment, albeit in a larger pen to accommodate large sows and litters. Details of pen fixtures, including the quality of the build, are therefore important to how they are perceived by farm staff – ensuring there's no piglet escape areas under the feeder may be a simple fix to increase a farmer's contentment with a system. It serves as a useful lesson to engage early with building companies to get the details right without compromising pen functionality.

7.2.3. Where does it work?

This system is designed for indoor fully slatted sheds. It could be retrofitted but requires 1-1.5m^2 more space than conventional farrowing crates.

7.2.4. How much does it cost?

Costs will depend on the specific system. The Pro-SAU project details costs of Stewa, Kink and Trapez at the time of the study in Euros and found there was additional costs compared to a conventional farrowing crate per sow per year of between €13.14 to €43.09 (Stewa-Trapez). The costing model was specific to the project and should not be used comparatively. Costs of alternative systems in the UK have been modelled recently by AHDB Pork and should be consulted for further information.

7.2.5. How can I do it well?

Adhere to the TC+ protocols for confinement between days -1 to +4 post-farrowing to optimise confinement period for piglet welfare and reduce compromise for sow welfare. Trialling loose nest-building and loose farrowing would enhance sow welfare but there are risks of increased piglet losses in the immediate post-farrowing period if sows are restless. A corner creep close to the sow's udder will assist piglet orientation towards the safe-zone.

System specific:

- Provide plentiful and accessible nest-building material. When crate is closed ensure sow can access material (e.g. fix a hessian sack to crate fittings, replenish substrate frequently).
- Consider choice of slurry removal system – a scraper system would allow greater provision of nesting materials as there is reduced risk of blockages in slurry removal.
- Move in sows 4-5 days before their due date and allow them to initially be loose.
- Get sows and gilts used to confinement by closing them in at feeding times, perhaps overnight (suggestion from TC-Basic farm staff – yet to be trialled) and close crate 1d before the due date.
- Leave crate closed 24h before farrowing and during early lactation to protect piglets. Evidence suggests that shutting sows in during active nest-building could be acutely stressful (Pedersen and Jensen, 2008b) having impacts on farrowing duration (Yun et al., 2015a). Having crates open during farrowing and early lactation risks increased piglet crushing, especially when using hyperprolific genetics (Yun et al., 2019b). The lack of space to avoid crushing piglets and/or to interact with them safely (e.g. grouping behaviour by sow) is suggested as a limiting factor for operating open ((Weber et al., 2009; Yun et al., 2019b) and when these systems were operated in an open position throughout farrowing and early lactation mortality levels were significantly higher (Heidinger et al., 2018).
- Ensure interactions, particularly during opening and closing, are positive. No forced or sudden movements, no loud voices. Suggest encouragement into the crate during confinement training with feed, enrichment. Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a).
- Confinement period should be no longer than 4 days post-farrowing.
- Open the crates individually (i.e. when the age of each litter is 4 days), rather than simultaneously as a batch.

- Open crates in the afternoon – evidence for reduced mortality compared to opening all at once in the morning (King et al., 2019b).
- Consider choice of slurry removal system – a scraper system would allow greater provision of nesting materials as there is reduced risk of blockages in slurry removal. This would allow retention of the fully slatted floor required to maintain hygiene.

General advice:

- Engage stock workers in renovation/design/retrofit process
- Provide staff training to new system
- Ensure building into which farrowing pens are fitted is optimal for workability, ventilation, lighting, staff safety – e.g. entry and exit points for pigs and staff can influence ease of movement
- Consider numbers per farrowing room for optimal workability (e.g. so that tasks can be performed in workable batches rather than large numbers all at once) and to reduce a contagion effect of disturbance (e.g. one hyper-reactive sow could cause problems throughout the farrowing room).
- Ensure suitable support structures are in place under foot (i.e. under the slats) to account for increased traffic in pens as a result of sows moving around more.
- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2018, 2019a)
- Select gilts with good leg strength and agility
- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline

7.2.6. How strong is the evidence?

The evidence for performance in these systems is high as a result of large commercial trials in Austria Pro-SAU complemented by large research trials. The system retains many features of the farrowing crate and therefore many of the welfare compromises remain high and evidence for compromises in a crate are well established. However, the duration of compromise is reduced with sows able to be loose 75% of the time in the farrowing house (if protocols are adhered to). Full welfare evaluations involve some recognition of duration of compromise (and opportunity for enhancements). Welfare opportunities are limited in the constraints of the system, however evidence for the benefits of providing nesting materials and enrichment for piglets is high. Evidence for optimising management to improve welfare (i.e. best practice for opening times) is moderate but is expected to increase with increased uptake of systems and heightened research activity.

7.2.7. Where can I find further information?

- Different temporary crating systems can be compared at: https://www.freefarrowing.org/farrowing-systems/temporary-crating/
- The SEGES final report evaluating 10 different housing options for loose lactating sows (including Temporary Crating Basic options) from a practical point of view can be found here or via http://svineproduktion.dk/Publikationer
- The Pro-SAU final report extensively evaluated temporary crate systems complaint with Austrian regulations with a minimum footprint of 5.5m^2. Access the English summary of the report here or the full final report (in German): https://raumberg-gumpenstein.at/?option=com_r_fodok&Itemid=200881&task=detail&publnr=19428
- AHDB Pork have completed an evidence report comparing the impact of alternative farrowing systems, including an economic assessment: https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf
- AHDB Pork's Knowledge Library has video material on temporary crating management: https://ahdb.org.uk/knowledge-library/temporary-confinement-farrowing-systems

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7.3. Temporary Crating ++

Impact summary

Temporary Crating ++ *is an alternative farrowing and lactation system built on a larger footprint to the conventional farrowing crate (6.0-7.5m^2). Although it retains fixtures to crate the sow it is designed for her to be loose the majority of the time and could be operated as zero-confinement depending on the piglet protection features, confidence of the staff and prolificacy of the sow. The system is typically installed on part-solid, part-slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a large separate, solid lying area (creep/nest) with a heat source. The creeps have adjustable, lockable fronts. If crating is used it happens either 1 day pre-farrowing or after the end of farrowing and up to a maximum of 4 days post-farrowing. Sows are provided with nesting material (usually chopped straw in a rack or hessian sack tied to front of crate) and piglets are provided with enrichment material (either point-source or chopped straw depending on flooring). It has the potential to offer greater welfare enhancements than TC-B and TC+ and ZC-Basic.*

Effectiveness		
	Improved piglet survival	**0**
	Improved sow welfare	++
	Improved piglet welfare	**+**
	Stockperson safety	**0**
	Hygiene	**+/-**
	Ease of management	**0**
	Other factors	
	Improved weaning weights	+
	Potential for price premium	**+/-**
Cost		
		£££
Speed of change		
		Moderate
Strength of evidence		
	Quality	Very High
	Context	Very High
	Overall	Very High

7.3.1. What is the system?

Temporary Crating ++ (TC++) is an alternative farrowing and lactation system built on a larger footprint to the conventional farrowing crate (6.0-7.5m^2). It is designed for the sow to be loose for the majority of the time but retains the option to temporarily confine her.

Examples: SWAP, Pro-Dromi®

SWAP by Skiold Jyden. Photo courtesy of V.A. Moustsen

Pro-Dromi® by Vereijken

Photos courtesy of J. Baumgartner, VetMedUni

System components: The system is typically installed on part-solid, part-slatted flooring above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a large separate, solid lying area (creep/nest) with a heat source. The creep fronts have lockable, adjustable fronts to allow retention for husbandry purposes or creep training. The crate component opens up fully to give the sow maximal movement within the constraints of the pen. Depending on the pen-type and creep size the amount of space afforded to the sow ranges from 5.5-6.5m^2 (creep space ~1.0m^2) and turning is unimpeded by fixtures and fittings. The rails of the crate provide protection for the piglets on one side and at least one sloped wall is provided on the other side to aid sow posture changes. It typically measures the length of the sow to support comfortable lying. Crate width when closed is more generous than conventional crates as it is designed to accommodate the dimensions of a hyperprolific sow and large litter. Zonation of areas for lying and dunging are more obvious with part slatted, part solid flooring (e.g. SWAP) or solid plastic panels in the crate/lying area for the sow when confined (Pro-Dromi®). Two feeders are offered in the SWAP to accommodate feeding when the crate is closed and a main feeder to accommodate optimal eating and eliminative behaviour to encourage good hygiene. The Pro-Dromi® has one feeder at the front designed for shared access with piglets later in lactation. Drinkers in the troughs and separate piglet drinkers are provided.

Husbandry: If crating is used it happens either 1 day pre-farrowing or after the end of farrowing and up to a maximum of 4 days post-farrowing. Sows are provided with nesting material (usually chopped straw in a rack or a hessian sack tied to the front of the crate depending on the flooring) and piglets are provided with enrichment material (either point-source or chopped straw depending on flooring or given the hessian sack in the creep to aid creep training). Solid piglet feed is often introduced during lactation.

7.3.2. How effective is it?

The balance of available evidence suggests there is no difference between piglet survival figures in the TC++ system using the confinement protocol described compared to permanent confinement. If the pen is to be used as a zero-confinement option the evidence suggests there will be greater risk of piglet mortality, especially if the sow is giving birth to large litters and equalisation has not taken place.

By allowing the crate to be opened for the majority of time, including during nest-building (if crate closed after farrowing has ended), there are marked welfare improvements for the sow compared to permanent crating. These improvements can affect the piglets, with potential for improved colostrum uptake, reflected in higher IgG levels and reduced activity during farrowing (Yun and Valros, 2015). As there is generally more space in the pen and when loose the sow can turn freely and move around the pen, welfare is markedly improved as she is able to turn around without obstruction with more autonomy over orientation within the pen and greater freedom of movement during lactation. It also allows increased ambulation in the lead up to farrowing which is a motivated behaviour in preparation for nest-building (Jensen, 1986). If the part-solid floored option is adopted there is potential for plentiful supply of nest-building material and later loose enrichment material for piglets which have known welfare benefits, including encouraging locomotor and object play. As the sows have less obstruction there is easy udder access equating to easier suckling success and evidence of heavier weaning weights (Pedersen et al., 2011).

Provision of a large, covered creep area near to the sow (but with access from a central passageway) offers a protected, thermally comfortable area for all piglets to access up until weaning. An attractive creep area for the piglets is also useful for stockpeople who can more easily access the piglets rather than having to get in and catch for husbandry, which therefore reduces negative human-animal interactions and reduced risk of spreading disease between pens. In addition, the creeps in the examples have lockable fronts making it easy to creep train and to retain piglets for husbandry purposes. To safe-guard piglets these lockable creep fronts have been designed with partitions to allow ventilation and prevent over heating whilst piglets are temporarily held inside. Although there is the ability to restrain the sow if necessary, stockperson safety could be at risk when staff and sows have to share the same space. The pen design will influence how much contact there needs to be, but it is important that staff learn to read the signals the sow is giving off and react appropriately to them. Thus, staff training is very important, as reported by commercial farmers reporting on how to make these systems successful, including *'Strict procedures are in place from the simplest of tasks to the more complex'*.

Zonation of areas to fulfil sow preference (via different flooring and more open areas in the intended dunging area via barred divisions between pens) for separate resting and dunging areas promotes hygienic conditions. If fully slatted flooring is used hygiene will also be promoted but the welfare benefits will not be considered as high because of the likely limited provision of enrichment material. In the SWAP consideration of where the main feeding trough is placed to promote optimum elimination behaviour also promotes hygiene (Andersen and Pedersen, 2011).

There are mixed reports relating to ease of management. Due to the larger pen sizes and intention for the sow to be loose the majority of the time, greater consideration is needed when deciding whether to enter the pen and perform tasks thus the potential for increased labour time. In a large evaluation of labour efficiency in these systems (Blumauer et al., 2018) several activities were documented, including interactions with piglets for husbandry tasks. Most tasks were on a par with farrowing crates but there were incidences when catching the piglets was delayed because of suckling happening away from the passageway and because piglets are being gathered in the creep, taken out, processed and then put back in it could take more time because piglets are not going directly into a trolley. Farmers with experience of these systems say that a new way of thinking about operating in the systems is needed and once you get used to these, routines develop, and labour becomes more efficient.

7.3.3. Where does it work?

This system is designed for indoor sheds on top of slurry pits but with part-slatted flooring. Retrofitting an existing barn would be challenging, especially if new flooring was required and it would involve reducing batch size due to the extra space required per sow place.

7.3.4. How much does it cost?

Costs will depend on the specific system. The Pro-SAU project details costs of SWAP and Pro-Dromi® at the time of the study in Euros and costed them at €66.02 and €152.58 more per sow per year than crates. The costing model was specific to the project and should not be used comparatively. What is comparative is that extra space is the main factor for increased costs. An approximate figure used in Denmark when consulting on costs of loose lactating pens is to factor ~350 £/m^2 extra in estimations. Costs of alternative systems in the UK have been modelled recently by AHDB Pork and should be consulted for further information.

7.3.5. How can I do it well?

Adhere to the TC++ protocols for minimal confinement and, if imposed, 4 days post-farrowing should be sufficient if the piglets are thriving.

System specific:

- Provide plentiful and accessible nest-building material. When crate is closed ensure sow can access material (e.g. fix a hessian sack to crate fittings, replenish substrate frequently).
- Move in sows 4-5 days before their due date and allow them to be loose.
- Get sows and gilts used to confinement by closing them in at feeding times, perhaps overnight (suggestion from TC-Basic farm staff – yet to be trialled) and if crate is to be closed before nesting close crate 24h before the due date. Try and avoid this if possible.
- Ensure interactions, particularly during opening and closing, are positive. No forced or sudden movements, no loud voices. Suggest encouragement into the crate during confinement training with feed, enrichment. Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a).
- Confinement period should be no longer than 4 days post-farrowing.
- Open the crates individually (i.e. when the age of each litter is 4 days)
- Open crates in the afternoon – evidence for reduced mortality compared to opening all at once in the morning (King et al., 2019b).

General advice:

- Engage stock workers in renovation/design/retrofit process
- Provide staff training to new system
- Ensure building into which farrowing pens are fitted is optimal for workability, ventilation, lighting, staff safety – e.g. entry and exit points for pigs and staff can influence ease of movement
- Consider numbers per farrowing room for optimal workability (e.g. so that tasks can be performed in workable batches rather than large numbers all at once) and to reduce a contagion effect of disturbance (e.g. one hyper-reactive sow could cause problems throughout the farrowing room)
- Ensure suitable support structures are in place under foot (i.e. under the slats) to account for increased traffic in pens as a result of sows moving around more.
- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2018, 2019a).
- Select gilts with good leg strength and agility.

- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline

7.3.6. How strong is the evidence?

The evidence for performance in these systems is high as a result of long-standing research trials in Denmark and The Netherlands and large commercial trials in Denmark, The Netherlands and Austria. The evidence about optimal confinement period has been well researched and confidence in the evidence about these systems is high. Evidence for optimising management to improve welfare (i.e. best practice for opening times) is moderate but given the number of farmers installing these systems practical recommendations are expected to increase, as is research.

7.3.7. Where can I find further information?

- Different temporary crating systems can be compared at: https://www.freefarrowing.org/farrowing-systems/temporary-crating/
- The SEGES final report evaluating 10 different housing options for loose lactating sows (including Temporary Crating Basic options) from a practical point of view can be found here or via http://svineproduktion.dk/Publikationer
- SEGES has multiple reports and resources on the development of the SWAP pen: SEGES has video material of SWAP in operation commercially: https://www.seges.tv/video/57397622/lose-soer-abning-ved-to
- PhD thesis studying alternative systems in Denmark (Janni Hales: https://ivh.ku.dk/research-files/awd-dokumenter/Janni_Hales_Pedersen_B5_PhD_thesis_2015.pdf
- The Pro-SAU final report extensively evaluated temporary crate systems complaint with Austrian regulations as well as larger pens like the SWAP and Pro-Dromi. Access the English summary of the report here or the full final report (in German): https://raumberg-gumpenstein.at/?option=com_r_fodok&Itemid=200881&task=detail&publnr=19428
- The Pro-Dromi® project is part of a long-standing programme of work at Wageningen University – more information can be found here:
- https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Pro-Dromi.htm
- Vereijken has clips of sows nesting and staff working in Pro-Dromi: https://www.youtube.com/watch?app=desktop&v=VL4oWMUkelQ
- AHDB Pork have completed an evidence report comparing the impact of alternative farrowing systems, including an economic assessment: https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf
- AHDB Pork's Knowledge Library has video material on temporary crating management: https://ahdb.org.uk/knowledge-library/temporary-confinement-farrowing-systems

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7.4. Zero-confinement – Basic

Impact summary

Zero-confinement-Basic *is an alternative farrowing and lactation system built on the same footprint as the conventional farrowing crate (≤5.0m^2). It has no possibility to crate the sow. The pen is basic with fully slatted flooring, built on top of slurry pits. Piglets are provided a separate, solid lying area (creep/nest) with a heat source. Farrowing rails surround the skirting of the pen. Inputs are expected to be compliant with legislation, therefore sows are provided with nesting material (usually chopped straw in a rack) and piglets are provided with point source enrichment such as wooden blocks on chains. Although there is no confinement of the sow, most other features are the same as a typical farrowing pen.*

Effectiveness		
	Improved piglet survival	**-**
	Improved sow welfare	+
	Improved piglet welfare	**+/-**
	Stockperson safety	**-**
	Hygiene	**+/-**
	Ease of management	**-**
	Other factors	
	Improved weaning weights	**+/-**
	Potential for price premium	**+/-**
Cost		
		£
Speed of change		
		Fast
Strength of evidence		
	Quality	Moderate
	Context	Low
	Overall	Moderate

7.4.1. What is the system?

Zero-Confinement Basic (ZC-Basic) is an alternative farrowing and lactation system built on the same footprint as a conventional farrowing crate (≤5.0m^2). It is designed to be an economical approach to removal of the farrowing crate. For the sow to be loose the majority of the time but retains the option to temporarily confine her.

Examples: Simple pen design no commercial name

Zero-Confinement Basic.
Image courtesy of V.A.Moustsen

System components: The system is typically installed on fully floor above slurry pits in temperature-controlled farrowing rooms. Piglets are provided a separate, solid lying area (creep/nest) with a heat source. There is no possibility to crate the sow, she is able to move freely in the space with ~3-4.0m^2 available to her, allowing turning unimpeded by fixtures and fittings. Piglet protection rails surround the base of the pen. Drinkers in or near the troughs and a separate piglet drinker is provided.

Husbandry: Sows are provided with nesting material (usually chopped straw in a rack) and piglets are provided with enrichment material, typically point source (e.g. wooden block on chain). Sows are fed twice a day.

7.4.2. How effective is it?

As there is limited evidence for any specific system in operation, some conclusions can be drawn by looking at data from TC-Basic systems operated in a fully open position, as well as knowledge of one large scale Danish commercial producer running pens like this. On balance it would suggest that there is a high risk of increased piglet mortality if using ZC-Basic, especially with hyperprolific breeding lines (Yun et al., 2019b). However, a commercial operation returns good results and has specific husbandry routines to optimise performance (see How can I do it well section).

By having no crate sow welfare is enhanced as she is permitted to turn around at all times and have autonomy over her orientation, and she is less at risk from injury by impeded turning given there is limited or no pen furniture. Not being confined during nest-building improves sow welfare (Nowland et al., 2019) and whilst there is strong evidence that space is more important than substrate for allowing the behavioural expression of nest-building (Hartsock and Barczewski, 1997; Jarvis et al., 2002), substrate is still very important (Rosvold et al., 2019) but limited in this system due to the necessity to have fully slatted flooring. With no potential for zonation of functional areas fully slatted flooring is required to maintain hygiene. Space is still reasonably limited so increased ambulation prior to nest-building is possible but reduced compared to larger systems. There are some indirect welfare enhancements for piglets when sows can nest-build freely, including improved maternal behaviour with reduced risk of savaging (Lawrence et al., 1994b) and reduced posture changes during farrowing (Yun and Valros, 2015). There's also evidence of improved farrowing progression in some studies (Oliviero et al., 2010). Welfare enhancements for piglets as a result of easier udder access with no crate bars blocking teats and higher weaning weights are a possibility based on evidence from non-crate systems (Pedersen et al. 2011) but there is limited data on these simple designs.

Because there is no ability to restrain the sow, stockperson safety is considered to be reduced in this system. There are no specific data on ease of management. For some tasks it will be more efficient, such as pressure washing due to limited pen furniture, for anything involving piglet handling a good human-animal relationship is essential to negotiate the potential for maternal defensiveness in early lactation.

7.4.3. Where does it work?

This system is designed for indoor sheds with fully slatted flooring on top of slurry pits. As there is no extra space required it can be retrofitted.

7.4.4. How much does it cost?

There are no data available on costs, but it is highly likely capital costs will be similar to farrowing crates. If performance is on a par with conventional crates these costs should remain similar to crates.

7.4.5. How can I do it well?

System specific:

- Reports from a producer doing it well stresses the importance of a quiet, calm farrowing house with set routines and diligent staff.
- This is needed to reduce the potential for overtly maternally defensive behaviour that might cause a contagion effect resulting in greater reactivity by sows and risks to piglets and staff.
- Examples of quiet, calm routines include piglet husbandry tasks either done outside of the farrowing barn or on the floor out of sight from the sow with cautious handling by skilled staff.
- Provide accessible nest-building material.
- Consider support structures that sows favour when lying down in order to promote careful, controlled lying movements (e.g. sloped walls rather than rails - (Damm et al., 2006)).
- Move in sows 4-5 days before their due date to settle them into single pens.
- Gentle sows in lead up to farrowing by engaging in positive contact – e.g. provide enrichment, not just food. Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a).

General advice:

- Engage stock workers in renovation/design/retrofit process
- Provide staff training to new system
- Ensure building into which farrowing pens are fitted is optimal for workability, ventilation, lighting, staff safety – e.g. entry and exit points for pigs and staff can influence ease of movement
- Consider numbers per farrowing room for optimal workability (e.g. so that tasks can be performed in workable batches rather than large numbers all at once) and to reduce a contagion effect of disturbance (e.g. one hyper-reactive sow could cause problems throughout the farrowing room).
- Ensure suitable support structures are in place under foot (i.e. under the slats) to account for increased traffic in pens as a result of sows moving around more.
- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2019a)
- Select gilts with good leg strength and agility
- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline

7.4.6. How strong is the evidence?

The evidence for performance is low. The evidence for the welfare benefits of allowing the sow to be loose is high and based on an extensive body of high-quality evidence. A low-to-moderate score is given overall.

7.4.7. Where can I find out more information?

- Information on pen components that promote piglet survival and aid sow posture changes can be found here:

  https://www.freefarrowing.org/farrowing-systems/specific-pen-features/

- Interview with loose housed sow manager on importance of routines can be found here: https://www.pigprogress.net/Piglets/Articles/2016/8/Bringing-together-housing-stockmanship-and-breeding-2851726W/

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7.5. Zero-Confinement +

Impact

Zero-Confinement + *is an alternative* farrowing and lactation system built on a larger footprint to the conventional crate (≥*6.5m*[2]*) typically on part-solid or solid floors in a temperature-controlled room. There is no possibility for confinement during farrowing. It has design features that allow zonation of the farrowing pen to allow separation of areas according to different functions. Separate dunging (slatted) and a separate lying/nesting (solid) areas are provided. Separate feeding areas are provided in some designs. Sloped walls and farrowing rails are provided for piglet protection and sow support. A separate, large solid-floored piglet nest/creep with a heat source that can accommodate all piglets until weaning. Ability to separate sow for husbandry practices is provided by closing sow temporarily in dunging area or feeder space. Inputs are expected to be compliant with legislation and sows are provided with plentiful nesting material loose long-stemmed straw (minimum 2kg) and enrichment material during lactation. There is potential for significant welfare opportunities in these systems.*

Effectiveness		
	Improved piglet survival	-
	Improved sow welfare	+++
	Improved piglet welfare	+++
	Stockperson safety	-
	Hygiene	+/-
	Ease of management	-
	Other factors	
	Improved weaning weight	+
	Potential for price premium	+
Cost		
		££££
Speed of change		
		Slow
Strength of evidence		
	Quality	High
	Context	Moderate
	Overall	Moderate

7.5.1. What is the system?

Zero-Confinement + (ZC+) is an alternative farrowing and lactation system built on a larger footprint to the conventional crate (≥$6.5m^2$). It is a system with high design specifications to create functional zones and promote good maternal behaviour (e.g. correct farrowing location, careful lying behaviour and pre-lying grouping of piglets) and good hygiene for both piglets and sow. Though there are different 'brands' of ZC+ with some individual design features, one thing they all have in common is the lack of crate to confine the sow.

Examples: Danish FF, Swiss FF, PigSAFE

Danish Free Farrower. Image courtesy of V.A. Moustsen

Swiss Free Farrower in operation (left) - image courtesy of SUISAG©) - based on FAT2 design by R. Weber (right).

PigSAFE pen. Image courtesy of M. Farish

System components: The pen is typically built on part-slatted, part-solid flooring with ample space provided for the sow to turnaround and move into different areas to fulfil different functions. Some systems (PigSAFE) have a separate, solid-sided feeding stall with the possibility to shut the sow in for safe husbandry procedures but no possibility of close confinement during farrowing or lactation. ZC+ has design features that allow zonation of the farrowing pen to allow separation of areas according to different functions. Separate dunging (slatted) and a separate lying/nesting (solid) areas are provided as a minimum. Pens can be built on top of a slurry pit or scraper system. Zonation of areas via differences in flooring types and wall divisions in some pens helps create temperature differentials, this also promotes good hygiene. In addition, barred areas in the dunging passage allows neighbouring sows to see and touch each other. Sloped walls and farrowing rails are provided for piglet protection and sow support during posture changes. A separate, covered piglet nest/creep with a heat source is large enough to accommodate all piglets until weaning and a lockable front. Ability to separate the sow for husbandry practices depends on the specific pen type – the Danish and Swiss designs do not have a mechanism, but PigSAFE does. Drinkers in or near the troughs and a separate piglet drinker is provided.

Husbandry: The sow is loose at all times and able to turn around freely. Plentiful nesting material of long-stemmed straw (>2kg) is provided daily, and enrichment material (such as straw) is provided throughout lactation. Sows are fed twice a day.

7.5.2. How effective is it?

The balance of available evidence is mixed for piglet survival, with reports from research trials suggesting that ZC+ systems can deliver equivalent piglet survival (e.g. (Edwards et al., 2012)) and others recording higher levels of mortality (Moustsen et al., 2013; Hales et al., 2014). In commercial trials inconsistencies are often reported, although there are typically improvements as staff and sows get used to the system (Andersen and Ocepek, 2020; Baxter and Edwards, 2021). ZC+ systems also have the largest available commercial datasets from national herd databases where crates have been prohibited since 1987, 1997 and 2000 for Sweden, Switzerland and Norway respectively. These should be treated with caution because we do not know the specific systems contributing to the dataset. We have discussed them under ZC+ but more basic designs as well as some TC data are likely to be in the datasets. However, the same can be true of any benchmarking exercise using large commercial datasets – details are lacking and sometimes details can be useful in troubleshooting problems or understanding good practice. From an extensive commercial dataset collected during the transition phase of removing farrowing crates, Switzerland have reported no difference between crates and Swiss ZC systems (Weber et al., 2009) and since then, despite an increase in litter size, they record good piglet survival levels with no change from those reported from previous studies with crates (Weber et al., 2020). Looking at data from the transition phase has provided an extensive dataset but should be treated with caution because it is not necessarily representative, given older crates were being replaced with newer pens. In Norway, national herd data (INGRIS) report consistent mortality figures and a large epidemiological study (Kielland et al., 2018) suggest mortality in current herds is better than 30 years previously when using crates. Caution should be adopted when making these historic comparisons, but it suggests both Switzerland and Norway achieve acceptable performance consistently in ZC+ systems. On the other hand, the Swedish herds have reported increased piglet mortality, particularly over recent years with a possible impact of large litter size contributing to the challenges (Olsson et al., 2018). Local/national differences in breeding strategies and controlling genetic inputs could be important factors contributing to differences, but this would require further investigation.

The ZC+ system is highly effective at improving sow and piglet welfare via provision of resources and system design criteria that meet the biological needs of the animals. By having no crate sow welfare is enhanced as she is permitted to turn around at all times and have autonomy over her orientation. The environments are designed to provide stimuli to enhance maternal behaviour (e.g. zonation, solid-sided nest-site) as well as a more dynamic environment to encourage locomotor, object and social play in piglets (Martin et al., 2015). Higher sow feed intake and higher weaning weights are reported (Baxter and Edwards 2021) in some trials and sows weaning in better condition to re-join their gestation group could have longer-term impacts on fitness (Ison et al., 2016). Some work in a straw pen kennel and run system showed an impact on subsequent litter size when pigs were weaned from these ZC systems compared to farrowing crates or temporary crating (King et al., 2019a).

Because there is no ability to restrain the sow, stockperson safety is considered to be reduced in this system, although PigSAFEs do have areas to separate the sow from staff. However, entry into the pen could still be necessary if sows do not want to enter the lockable space. There is no recent evidence on ease of management in ZC+ pens, however studies following staff in Swedish ZC systems report increased labour mainly to deal with straw provision and mucking out (Olsson et al., 2009). Some useful insights into pen designs and optimising working routines for staff safety as well as comfort have also been conducted that can inform design considerations to optimise ergonomics (Olsson et al., 2010). More recent data are needed, especially to determine how well staff deal with the potential for increased handling of large litters. Verbal farmer reports suggest that anything involving piglet handling means a good human-animal relationship is critical to negotiate the potential for maternal defensiveness in early lactation. A recent study in Australia (Hayes et al., 2021b) testing fearfulness in piglets reared in loose (PigSAFE) vs. crates suggests the high walls in PigSAFE (designed to offer the sow a sense of enclosure) may result in more reactive piglets and sows, which has the potential to disrupt the human-animal relationship and therefore influence ease of management, as well as impact piglet fearfulness. In general, on the balance of evidence and the understanding that each ZC+ system is different, further information and optimisation is needed to balance staff needs with those of the sow and piglets.

7.5.3. Where does it work?

This system is designed for indoor sheds on either solid or partly solid floors. The increased space means retrofitting would reduce number of animals per building.

7.5.4. How much does it cost?

Data are available for Danish FF and PigSAFE – both have increased costs. Danish FF would cost £12.97 per sow per year and PigSAFE would cost £13.46 per sow per year compared to crates at £12.52 – thus between £0.45-0.94 costs per weaner more expensive. This assumes same performance as crates.

7.5.5. How can I do it well?

System specific:

- Each design of the ZC+ system is different, and the details of that design can be critical in how well it performs.
- Common recommendations involve the importance of gentling the sows from gilt, through mating and gestation and in the lead up to farrowing by engaging in positive contact – e.g. provide enrichment, not just food.
- For gilts or sows experiencing the pens for the first time it will be important to show the sows where the resources are – especially drinkers.
- Developing routines for efficient and calm handling of the piglets, including performing husbandry procedures that are aversive (i.e. piglet processing) away from nest-site, ideally in a separate room or by handling without piglets making noise.
- Developing this good human-sow relationship prior to farrowing could help mitigate any potential safety issues post farrowing and careful/considered handling of piglets post-farrowing also reduces fearfulness (Muns et al., 2015; Hayes et al., 2021a).
- Minimal disturbance, particularly around new mothers and litters is critical to help promote good maternal behaviour and reduce requirements for intervention.

General advice:

- Engage stock workers in renovation/design/retrofit process
- Provide staff training to new system
- Ensure building into which farrowing pens are fitted is optimal for workability, ventilation, lighting, staff safety – e.g. entry and exit points for pigs and staff can influence ease of movement
- Consider numbers per farrowing room for optimal workability (e.g. so that tasks can be performed in workable batches rather than large numbers all at once) and to reduce a contagion effect of disturbance (e.g. one hyper-reactive sow could cause problems throughout the farrowing room)
- Ensure suitable support structures are in place under foot (i.e. under the slats) to account for increased traffic in pens as a result of sows moving around more.

- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2018, 2019a).
- Select gilts with good leg strength and agility
- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline
- Consideration of genetic selection is important for improving maternal behaviour whilst maintaining docility with staff – more research is required and an active dialogue between the customer and the breeding company.

7.5.6. How strong is the evidence?

The evidence for performance is moderate with high quality research trials and trials under commercial conditions being undertaken. Systems are also in operation commercially in some countries. The evidence for the welfare benefits of providing resources to meet biological needs is high. The evidence on stockperson wellbeing is more limited and based on farmer verbal reports.

7.5.7. Where can I find further information?

- Different zero-confinement systems can be compared at: https://www.freefarrowing.org/farrowing-systems/individual-farrowing-pens/
- Specific tips for free farrowing husbandry and best practice protocols can be found here: https://www.freefarrowing.org/farmer-resources/free-farrowing-husbandry/
- AHDB Pork have completed an evidence report comparing the impact of alternative farrowing systems, including an economic assessment: https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf

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7.6. Group farrowing and two-stage multisuckle systems

Impact

Group farrowing and two-stage multisuckle systems *allow sows and litters to mix before weaning. The majority are based on multi-suckling accommodation and are generally deep-litter systems, although there are Dutch systems trialled on fully-slatted flooring and two-stage systems trialled in Australia where pigs move from individual ZC pens or farrowing crates to a separate barn for lactation. Whilst they take up more space the deep-litter systems are considered low cost compared to individual pens which require more pen furniture and use of temperature-controlled farrowing houses. Deep litter systems were common in Sweden during the transition phase away from crating. The versions being trialled in The Netherlands and Germany have part-slatted flooring and operate in temperature-controlled rooms, thus increasing costs. The two-stage system is intended to reduce costs by allowing more sophisticated individual accommodation used for the first two weeks to be emptied, cleaned and refilled more quickly when the current batch is moved to multisuckle. For this appraisal the effectiveness will assume that sows are ZC throughout (i.e. no use of crates during two-stage).*

Effectiveness		
	Improved piglet survival	**-**
	Improved sow welfare	+++
	Improved piglet welfare	++
	Stockperson safety	**-**
	Hygiene	**+/-**
	Ease of management	**-**
	Other factors	
	Improved weaning weight	**+/-**
	Potential for price premium	**+**
Cost		
		££
Speed of change		
		Moderate
Strength of evidence		
	Quality	Low
	Context	Moderate
	Overall	Low

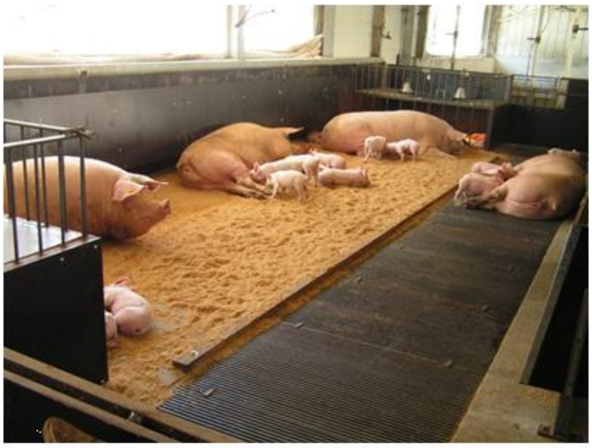
7.6.1. What is the system?

Group farrowing and two-stage multisuckle (GF) is an alternative farrowing and lactation system where expectant sows move as a batch farrowing group into communal accommodation with voluntary individual nest-boxes in which to farrow. It is based on mirroring the natural behaviour of sows to retreat away from their social group around farrowing, nurse their young privately for the first few weeks before reintegrating with the group.

Examples: Swedish deep litter systems. Dutch group lactation. Australian two-stage

Group farrowing and lactation systems in naturally ventilated barn, deep bedding and individual nest-boxes which are removed about 2 weeks after farrowing. Photos courtesy of www.freefarrowing.org

Multi-suckle in The Netherlands on part-slatted flooring with hessian sacks as nesting/ enrichment materials. Image supplied courtesy of C. van der Peet-Schwering, Wageningen University



Two-stage multisuckle accommodation. Sows farrow individually in more conventional accommodation before being moved to another barn for lactation. Image courtesy of R. Morrison.

System components: There is no possibility for close confinement of the sow in crates (we assume ZC is used in two-stage for this scenario). Traditionally these systems involve housing in large naturally ventilated barns with deep-straw bedding, lined with bedded individual nest-boxes (~5m^2). Nest-boxes have a basic design with a threshold across the entrance way to prevent piglets escaping until they are old enough to mix. Some have a lockable door.

Husbandry: Sows either have voluntary access in and out of the nest boxes or they are locked in close to their due date before releasing back into the communal area typically when piglets are 7-14 days old. In the deep litter systems nest-boxes are often removed and the sows and litters multisuckle for the remainder of lactation. The systems in the Netherlands and Germany are not bedded so operate in temperature-controlled rooms increasing the costs of inputs. Nesting material/Enrichment is either deep straw or hessian sacks. Some systems take piglets to a higher weaning age and utilise lactational oestrus to serve sows whilst they are still lactating. This will not be discussed here. Water availability is outside the nest-box unless boxes are locked for farrowing. Floor feeding is typical twice a day pre-integration and when fully integrated piglets can eat from the sow feeders typically available ad libitum.

7.6.2. How effective is it?

The balance of available evidence suggests GF systems return reduced piglet survival rates compared to conventional systems. Recent German work implicates high litter sizes and simple pen design, including issues with smaller pen space (5m^2 vs. 6m^2 returned higher mortality) for the individual nest-boxes, for increasing the risk of mortality (Grimberg-Henrici et al., 2019). This study did not equalise litters until 2 days post-farrowing and it therefore highlights the importance of early intervention (ensuring early colostrum intake then equalisation so all piglets have a teat) with large litters and the potential challenges with doing that in this group system. Upon re-mixing, particularly if moved to a different location, reports of missed sucklings and increased crush risks are not uncommon. Cross-suckling risks reduced growth rate for more vulnerable piglets.

The GF systems do however increase welfare opportunities for sows and their litters as they meet many of the behavioural needs of the animals, particular social and reintegration needs and reduce long-term aggression (van Nieuwamerongen et al., 2014; Verdon et al., 2019). There are also risks that sow-sow aggression will occur, particularly upon remixing in two-stage systems, and this risks the piglets' welfare. No confinement, greater space allowance and more dynamic environments can all be considered positive for animal welfare. Greater feed intakes for sows and higher weight gains for piglets are reported in some research, but not all (Verdon et al., 2016), with some research suggesting long-term benefits from avoiding the 'weaning-check' in piglets (van Nieuwamerongen et al., 2015). Because there is very little control over the immediate farrowing and early lactation environment the system is more reliant on good maternal behaviour and production of robust piglets in litter sizes that the sow can nurse without interference. Thus, it is sensitive to the type of genetics used and is closer to the outdoor system in how it might operate successfully.

As there is no ability to restrain the sow stockperson safety is considered to be reduced in this system and ease of management will depend on the human-animal relationship and on set routines. Verbal reports from a Swedish farmer operating deep litter multisuckle suggests very sensitive management is required to ensure successful carrying out of tasks particularly related to early piglet husbandry.

7.6.3. Where does it work?

This system is designed for naturally ventilated sheds/barns on solid floors with deep litter or temperature-controlled rooms on part-solid floors.

7.6.4. How much does it cost?

There is no information on costs. Costs will depend on how sophisticated the nest-boxes are and whether additional design features are put in place to improve piglet survival and staff ease of management. Also, the space needed for the group-pens.

7.6.5. How can I do it well?

System specific:

- Sow numbers per batch should be no more than 8 and the group should be stable before entry into communal farrowing accommodation.
- Consider design features to protect piglets in the nest-boxes, such as sloped walls to aid sow posture changes (Damm et al. 2006).
- Developing routines for efficient and calm handling of the piglets, including performing husbandry procedures that are aversive (i.e. piglet processing) in safe areas is important.
- Minimal disturbance, particularly around new mothers and litters is critical to help promote good maternal behaviour and reduce requirements for intervention
- Mixing of piglets during lactation should only be done when the youngest litter is robust enough to be mixed (typically no earlier than 7 days).
- Ensuring piglet health and vigour before mixing with other litters is important to reduce likelihood of problems during late lactation and the difficulties with individual care.

General advice:

- Engage stock workers in renovation/design/retrofit process
- Provide staff training to new system
- Operate one farrowing system to allow sows and staff to adapt – evidence that consistency improves performance (King et al., 2018, 2019a)
- Select gilts with good leg strength and agility
- Select gilts with good udders with teats evenly spaced and rows at an optimal distance from the midline
- Consideration of genetic selection is important for improving maternal behaviour whilst maintaining docility with staff – more research is required and an active dialogue between the customer and the breeding company.

7.6.6. How strong is the evidence?

The evidence for performance is moderate with high quality research trials but limited data commercially. The evidence for the welfare benefits for both sows and piglets of providing resources to meet biological needs is high. The evidence on stockperson wellbeing is more limited and based on farmer verbal reports.

7.6.7. Where can I find further information?

- Different group systems can be compared at: https://www.freefarrowing.org/farrowing-systems/group-systems/
- AHDB Pork have completed an evidence report comparing the impact of alternative farrowing systems, including an economic assessment: https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/COP/AHDB%20Alternative%20Farrowing%20Report.pdf
- PhD thesis of S.E. van Nieuwamerongen on Development of pigs raised in a group housing system for lactating sows and their litters https://edepot.wur.nl/409859

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8. The Five Domains Approach to Farrowing Systems

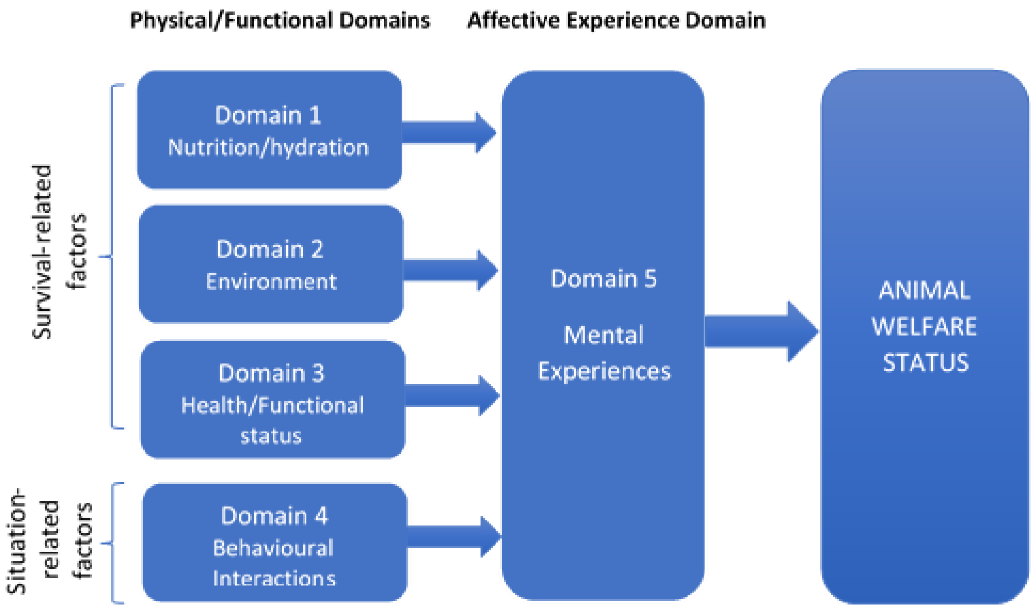
8.1. Five domains methodology

The 'Five Domains' model is a method of assessing welfare impact (Mellor, 2017; Mellor et al., 2020b). The domains relate to physical (or functional) factors (Domains 1-4) and how they impact on mental experiences (Domain 5). Many welfare assessments look at the physical state of the animal but that is not enough without interpreting what that actually means for the animal's mental state. The Five Domains recognises that physical and mental well-being are inextricably linked. How an animal mentally experiences its own life matters, and many physical and behavioural interactions give rise to specific subjective mental experiences (usually termed affects). It also recognises that these can be both positive and negative.

The 4 physical/functional domains relate to impacts or opportunities regarding:

- Nutrition/hydration status
- Environment – physical, sensory
- Heath/functional status (disease, injury, functional impairment)
- Behavioural interaction (with the environment, other animals, humans)

The first 3 are grouped into survival-related factors as disruption or internal imbalance could be survival-critical (e.g. no water/food supply). The 4th domain involves situation-related factors (e.g. negative handling, aggression from other animals). The four physical domains infer potential negatives and positive impacts in the 5th domain and these mental experiences are most directly relevant to the animal's welfare state. For example, negative experiences in domain 5 result from restrictions on/inadequacies/problems within each physical domain and positive experiences in domain 5 result from opportunities/enhancing conditions/achievements within each physical domain. This simple diagram shows how the domains combine to determine an animal's welfare status.



Application of the 5 domains to farrowing and lactation systems

It was not possible to fully apply a 5 domains welfare assessment to farrowing and lactation systems in the short time window for this REA and it would be more appropriate to approach a number of different panellists to discuss and then use the framework to judge the different system scenarios proposed here. New Zealand's National Animal Welfare Advisory Committee (NAWAC) are attempting a similar exercise and it has involved consultation and training with Massey University (original creators of the 5 domains model) and a panel of experts from NAWAC. EFSA are also undertaking a risk assessment relating to farrowing systems and though they are not using the 5 domains approach, they have a panel of experts assessing an expansive list of welfare consequences, discussing and scoring accordingly. Therefore, in this REA we propose explaining the 5 domains approach, summarising the different welfare compromises/enhancements relating to farrowing systems, populating the domains tables and proposing a grading system in readiness for further discussion and potential application.

The 5 domains model can be thought of as a check-list involving several steps that would typically result in an overall welfare 'score' of what the animal is experiencing.

Step 1: Identifying welfare compromises and enhancements
Welfare compromises and enhancements relating to the farrowing environment have already been summarised in the critical review section. These are then catalogued into the 4 physical domains and more specific thinking about which mental experiences are likely to arise from those is applied. Some caution here - whilst there have been significant advances in determining animals' emotional state it remains subjective and therefore, we must infer mental experiences. Justification for this inference is based on the measurable/observable evidence (i.e. from data collected on the physical domains (1-4)). Some indicators are widely validated with ample evidence such as the animal's physiological state and/or its productivity (see critical review). Other aspects such as the proposed mental experience are less often validated, in part because of the difficulty with collecting this evidence.

In general, when wanting to infer something about the animals' mental experiences, animal-based indicators (i.e. descriptors of the outcome of the situation for the animal) are preferred over resource-based indicators (descriptors of the inputs they are given). However, resource-based indicators can be equally important because they allow assessment of the potential for compromise and/or enhancement if the resource is used. They serve as a proxy for the risk/opportunity for negative and positive experiences and can be thought of as 'it might' happen whereas animal-based indicators can be thought of as 'it does happen'. Effort is made, though, to look for evidence of utilised opportunities not just provided opportunities. For example, we know that certain nesting materials may be more favourable than others as indicated by observable differences in the sow's interaction with them (e.g. (Rosvold et al., 2018)).

Step 2: Grading welfare compromise and enhancement
The second stage involves grading the negatives and positives in order to come up with an overall score.

Compromise can be graded using a five-tier scale (A-E), where the tiers represent A none, B low, C mild to moderate, D marked to severe, E very severe, ranging from no or tolerably low intensity negative mental experiences to exceptionally unpleasant experiences manifesting as negative mental experiences at very high intensities (i.e. very severe). The overall welfare compromise grade integrates the quality of the negative experience, its estimated intensity (based where possible on objective measurable evidence) and its estimated duration. For example, farrowing pain may be graded high on intensity (given what we know about the sow's capacity to experience pain – Ison et al. 2016) but low on duration, although this depends on your time horizons. A prolonged farrowing duration of hours maybe significant to the sow at the time but less significant in the context of a whole lifetime. So, it may receive an overall grade of moderate welfare compromise. Similarly, a fatal crush may initially have a high intensity rating of very severe but would be almost instantaneously fatal thus downgraded. A traumatic, non-fatal injury however would score higher due to the potential for protracted suffering, even if it did not result in death. It should also be noted that the absence of a negative affect (i.e. score None) does not mean the presence of positive experiences.

Mellor et al. (2020) suggests enhancement can be graded using a four-tier scale (0, +, ++, +++), where the tiers represent "no", "low-level", "medium-level" and "high-level" enhancement, respectively.

The grading scale for opportunity and use should be applied separately and relates to whether you are taking a resource-based approach or an animal-based approach to the assessment. The resource-based approach is the availability of opportunities for animals to engage in self-motivated rewarding behaviours, and the animal-based approach is the animals' actual utilisation of those opportunities. For example, sows may be given access to manipulable material with which to nest-build, however, depending on the quality, timing and placement of the provision they may or may not use it.

Step 3: Scoring confidence in the evidence

The degree of confidence in the evidence is then scored. For example:
0 = no animal data available – but possible negative experiences could be inferred from human reports
1 = low confidence – there is a need for more specific/detailed animal data
2 = moderate confidence – clarification would come from more specific/detailed animal data
3 = high confidence – sufficient animal data available

Step 4: Likelihood:

The likelihood of any given animal experiencing the compromise/enhancement is then scored and the severity and the duration of the compromise/enhancement are also incorporated into an overall welfare score.

- Never / Not Applicable
- Low likelihood
- Moderate likelihood
- High likelihood

Percentages of animals in a population experiencing the compromise/enhancement could be added to the likelihood categories and then, where quantifiable data are provided, you could make a more informed decision. For example, it is reported that the causes of piglet mortality are different in different systems and if you were grading the likelihood of a piglet experiencing a certain type of death you could use post-mortem data to make a judgement on likelihood.

Step 5: Overall grading

An overall grading would then be made based on a combination of these different scores.

To do this in practice involves setting scenarios (i.e. different farrowing systems) and giving a set of assumptions.

Identifying welfare impacts and opportunities

Which experiences can sows and piglets have?

The below Figures list identified welfare impacts and opportunities in each domain and their associated mental experiences (Domain 5) for sows (S) and piglets (P). Note that many of the conditions have a physical and behavioural element and will therefore appear in several domains, but the mental experiences associated with them are described according to that domain. For example, restriction of space has a physical impact (Domain 2) but also a behavioural one as it can limit behavioural opportunities (Domain 4). Similarly, a health factor such as injury has an obvious negative affect of pain (physiological response), but the behavioural component associated with receiving that injury would also be scored under behavioural interaction (e.g. lameness and inability to feed). The tables should also be approached with caution as for some conditions they list the potential for welfare compromise and enhancements but for certain factors not all animals will experience these situations (i.e. risks vs. outcome). For example, not all piglets will experience trauma. This would be incorporated into the likelihood score as part of the grading system proposed above.

Domain 1 and 5: Nutritional Conditions and their Associated mental experiences

Negative Conditions		Positive conditions	
Nutritional inadequacies	Negative mental experiences	Nutritional opportunities	Positive mental experiences
Significant restricted feeding (S)	Hunger, fatigue, including potential for fatigue during farrowing	Optimal feeding opportunities on a balanced diet	Postprandial satiety, energetic feelings
Starvation (P)	Hunger, weakness, thermal discomfort as a result of insufficient colostrum/milk intake to aid thermogenesis	Eating correct quantities of food (includes suckling sufficient colostrum/milk (P)	Comfort of satiety, including gastrointestinal comfort, energetic feelings, gastrointestinal comfort Thermal comfort
Lack of variety (S + P)	Boredom, malaise, monotony	Variable food	Pleasure of tastes/smells/textures
High maternal investment (S)	Hunger, lethargy, mental experiences of having a low body condition score, and of metabolic and pathophysiological conditions		
Voluntary over-eating, excessive energy intake (S): physical and metabolic consequence (e.g. MMA – but see domain 3)	Discomfort, pain as a result of experiencing farrowing difficulty Mental experiences of being too fat or thin, and of metabolic and pathophysiological conditions	Eating a balanced diet	Satiety, feelings of being energetically balanced

Restricted water intake (S)	Thirst	Drink correct quantities of water	Wetting/quenching pleasures of drinking

Domain 2 and 5: Physical Environmental Conditions and their Associated Mental experiences

Negative Conditions		Positive conditions	
Unavoidable physical conditions:	Negative mental experiences – forms of discomfort:	Enhanced physical conditions:	Positive mental experiences – forms of comfort
Close confinement (S)	Physical: discomfort from general stiffness, discomfort as unable to perform posture changes comfortably, including thermal discomfort from being unable to adopt postures necessary for thermal comfort	Space for moving freely, turning around, performing motivated behaviours	Physical comfort, pleasant feelings from hormonal feedback associated with performing motivated behaviours
Restricted space (S+P), overcrowding (P)	Physical: general musculoskeletal pain, discomfort from skin irritation from prolonged contact with hard surface, thermal discomfort from inability to engage properly in posture changes associated with thermal comfort (e.g. lateral lying), unpleasant feeling of unhygienic conditions due to inability to separate dunging, eating and resting activities	Space for spontaneous locomotion, including play	Physical comfort Pleasant feelings from fitness, exercise
Unsuitable flooring (S+P)	Physical: general musculoskeletal pain from e.g. lameness, discomfort from skin irritation (e.g. abrasiveness during suckling), fatigue from inability to engage in adequate resting and sleep activities, unpleasant feelings of unhygienic environment	Suitable flooring	Physical comfort, warmth, coolness, well rested
Unsuitable substrate, wet/soiled ground (S+P)		Suitable substrate, well-drained ground, hygienic	

	Thermal discomfort, chilling from wet lying area, unpleasant feeling of unhygienic conditions due build-up of faecal material		
Thermal extremes (S+P)	Thermal: Chilling, overheating	Effective temperature control	Thermal comfort
Unsuitable/inadequate microclimate provision (P)	Thermal: Chilling from limited access to heat source	Effective shelter and shade available for outdoor conditions	
Loud or otherwise unpleasant noise, inescapable noise (S+P)	Auditory: impaired hearing or ear pain	Effective noise control measures in place	Auditory comfort
Unpredictable events (S+P)	Anxiety, fear, hypervigilance	Predictability achieved through established routines	Relaxation-based ease and calmness
Physical limits on rest or sleep (S+P)	Exhaustion	Conditions conducive to rest and sleep	Well rested
Poor physical fitness, muscle de-conditioning (S+P)	Physical weakness and exhaustion	Poor fitness	Vitality of fitness and pleasurably vigorous exercise

Domains 3 and 5. Health conditions and their Associated mental experiences

Negative Conditions		Positive conditions	
Presence of:	Negative mental experiences:	Minimal or no:	Positive mental experiences
Injury: fatal crush, fatal savaging attack (P)	Pain, fear, breathlessness	Injury	Comfort, good health and functional capacity
Injury: non-fatal trauma (e.g. trampled, trapped, savaging) (P)	Pain, fear, breathlessness, debility, weakness		
Injury: Husbandry mutilations (P)			
Injury: outcome of unsuitable system component from Domain 2 (flooring, fixtures, fittings) – e.g. abrasion, lesion (S+P), pressure sore (S)	Pain, skin irritation, discomfort		
Injury: outcome of domain 4 effects - unsuitable social dynamic, aggression (S+P)	Pain, skin irritation from lesions, fear		
Sunburn (S+P)	Pain, skin irritation, discomfort	Sunburn	Comfort

Disease relating to sow (acute, chronic), MMA (P)	Pain, discomfort, weakness, malaise	Disease	Comfort, good health
Disease: scour (P)	Pain, thirst, weakness, sickness, malaise		
Functional impairment: from farrowing problems (S)	Pain, fatigue	Functional impairment	Comfort, good health
Functional impairment: from birthing difficulty, crush/suffocation (P)	Pain, breathlessness, debility, lethargy, confusion, dizziness, thermal discomfort associated with hypoxia		Comfort, good health, thermal comfort
Functional impairment: from gastrointestinal complications due to insufficient transfer of passive immunity (P)	Pain, debility, weakness, lethargy, thermal discomfort		

Domains 4 and 5: Behavioural Interactions and their Associated Mental experiences

Interactions with the environment			
Negative Conditions		Positive conditions	
Exercise of 'agency' is impeded by:	Negative mental experiences:	Exercise of 'agency' is promoted by:	Positive mental experiences
Close confinement (S) Restricted space (P+S)	Lack of choice/agency, anxiety, boredom, frustration, thwarted motivation to nest, play or forage	Space for moving freely, turning around, performing motivated behaviours, including nesting, spontaneous locomotion, including play	Interested, engaged with activities afforded by unrestricted space, pleasantly occupied, satisfied by performing motivated behaviours, novelty, energised, focussed, optimistic mood
Unsuitable flooring (S+P)	Lack of choice/agency to distinguish functional areas and perform comfort behaviours (e.g. wallowing, thermoregulation) and motivated behaviours (e.g. digging, rooting)	Suitable flooring	
Lack of and/or unsuitable nesting (S), enrichment material (S+P)	Frustration due to inability to perform motivated and engaging behaviours, boredom, negative outlook/mood	Availability of suitable, varied (and plentiful) nesting and enrichment material, exploration, foraging	
Choices markedly restricted by	Lack of choice/agency to separate functional areas, boredom,	Varied/dynamic/complex environment, exploration, foraging	

unvaried, barren space (S+P)	withdrawal, , negative outlook/mood		
Inescapable sensory impositions	Various combinations: startled by unexpected events, neophobia, hypervigilance, frustration, anger, negative outlook/mood, learned helplessness	Congenial sensory inputs	Calmness, feelings of control, optimistic mood
	Interactions with other animals		
Inadequate maternal attention (P)	Insecurity	Positive maternal attention	Security, comfort, bonded, satisfaction
Mismothering (e.g. savaging) (P)	Pain, anxiety, fear, panic	Positive maternal behaviour	
Maternal separation (P)	Fear, anxiety, frustration	Maternal contact	
Inadequate mothering ability (e.g. gilts fearful of piglets) (S)	Neophobia, anxiety	Positive maternal behaviour	
Negative piglet-piglet interaction, competition (P)	Pain, anxiety, fear, panic	Positive piglet-piglet interaction, engaging in play	Pleasure, reward, bonded,
Inability to interact with piglets (S)	Frustration	Ability to interact freely with piglets	Feelings of control, comfort, bonded, reward
Inability to separate from piglets (S)	Frustration, pain	Ability to separate from piglets	Feelings of control, physical comfort
Inability to interact with other sows when motivated to do so (e.g. reintegration during lactation) (S)	Frustration, anxiety, loneliness	Ability to interact with other sows (s)	Feelings of control, satisfaction of motivated behaviours to integrate
Negative social behaviour with sows, including inability to withdraw from social interactions (e.g. before farrowing) (S)	Fear, pain, aggression, loneliness, anxiety	Positive social behaviours with sows	Comfort, pleasure
	Interactions with humans		
Negative human-animal interaction: Capture and restraint (P+S), treatment, mutilation from husbandry procedure (P)	Fear, anxiety, pain, uncertainty, anger, frustration, insecurity, confusion, negative outlook/mood	Positive human-animal interaction: feeding, resource provision	Confidence, feeling in control, positive anticipation
Attitude of humans: uncertain, fearful, impatient, oppressive, insensitive,	Behaviours: hypervigilance, freezing, flight/escape and avoidance, startle	Attitude: confident, caring, sensitive, emphatic, patient, kind	Behaviours: short flight distance, at ease with interactions, seeking

belligerent, domineering, callous, cruel, vindictive Voice: hesitant, angry, loud, shouting, inconsistent Aptitude: inexperienced, unskilled, untrained, unqualified, neglectful	vocalisations, withdrawn, non-compliant	Voice: confident, calm, clear, encouraging, pleasant, consistent Aptitude: experienced, skilled, trained, qualified, vigilant	contact with humans, explores novelty, compliant, responsive

Validity of Domain tables

The validity of summarising the potential welfare compromises/opportunities in these tables comes from our scientific understanding of the condition and the physiological consequences relating to any disruption or imbalance to the animal. For example, we know that dystocia (a disrupted or difficult labour) has physiological consequences for the sow and piglets. It depletes energy stores and stimulates nociceptors and nociceptive pathways, that are then processed in the central nervous system of the sow who can then perceive pain. For piglets experiencing a protracted birth, there is potential for meconium aspiration syndrome in the peri-partum period, causing oxygen deprivation at birth and reduced neurological capacity and compromised thermoregulation post-partum (Alonso-Spilsbury et al. 2005). We also know from our understanding of the neurophysiological pathways in pigs that they are able to perceive pain, although there is some evidence about the piglet's capacity to perceive pain during the farrowing process (Baxter and Edwards, 2018). The mental experience of pain or the “unpleasantness” of pain is also known from studies looking at responses to painful stimuli, including avoidance behaviours, as well as responsiveness to treating pain (see Ison et al. 2016 for review). Thus, we are confident in saying that farrowing difficulties can result in pain for the sow. When we think about opportunities for animals to gain welfare enhancements (e.g. from environmental choice), evidence from behavioural-neuroscience is used to support the inference of a rewarding mental experiences in animals making choices to engage with their environment. Coherence between multiple indicators (e.g. behaviour and physiology) further strengthens the case for inclusion of these parameters in the welfare assessment.

Caveats for the 5 domains approach

There are number of notes of caution when trying to apply this method and any method that attempts to assign an overall welfare score. Some have been noted in the text above but will be repeated here.

- Overlapping scores – many of the conditions can appear in several domains
- Potential for double counting
- Enhancements scores on 1-4 scale but compromises on a 5-tier scale could be problematic with possibilities to score ‘down the middle’ for compromises but forced to make a decision for enhancements.
- Assessing scenarios involves making assumptions and making assumptions may result in lost detail which could be important to determining the success of a system, for example.

9. Limitations/feedback of REA process

The target of the REAs are syntheses where evidence from multiple sources has been collated and evaluated. This process should allow relevant, robust data to be quickly identified. However, the suggestion for REAs for literature searches is to start with reviews and expand. There is a danger with this process that the reviews themselves are not as comprehensive as required and/or that they stipulate the weaknesses of summarising information. Specifically for this case that summarising can result in the loss of details of particular studies that might contribute to explaining performance figures. For example, breed differences, sow parity and previous experiences, the similarity between dry sow accommodation and farrowing accommodation have all been shown to influence piglet survival.

We also reiterate our specific caveats regarding performance information as an example. A main aspect of this REA was to look at piglet mortality in different systems. When comparing housing systems, it should be the performance of the system that's compared, so including all piglets born in the system and analysis will be at the batch-level. However, when analysing information at batch-level, information about the individual litter cannot be included, so as supplementary analysis, piglet mortality at sow level can be analysed to learn about effects of things like littersize, parity, age at death etc. In many publications the focus is at sow level, which is more reflective of the sow and potential interactions between sows and piglets rather than the system. This could be particularly relevant when comparing performance in systems housing hyper-prolific sows because analysis at sow level will not include all piglets because some are moved to foster sows and if it does include all piglets, they will have experienced different conditions of either being raised by the biological sow or a nurse sow, and moved to other litters during the lactation period. We therefore urge caution when looking at summary data.

The subject matter is vast and the REA is likely to have benefitted from the authors' work in the field, production of past reviews and collaborations with academics and industry nationally and internationally to gather additional, relevant information. Even with this groundwork the REA process was incredibly intensive and difficult to keep succinct. However, the EFI protocol for the narrative summaries was useful and focussed the synopsis to the relevant information. One problem we did encounter was that the scoring system for the narrative summaries could do with an extra level - we would propose 0/- and would have used this to score a number factors where the evidence for performance is either the same or lower, not either side at +/- and not equal at 0.

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