How Mine, Task, and System Characteristics Influence Mine Leaders' Perceptions of PDSs for Mobile Machines

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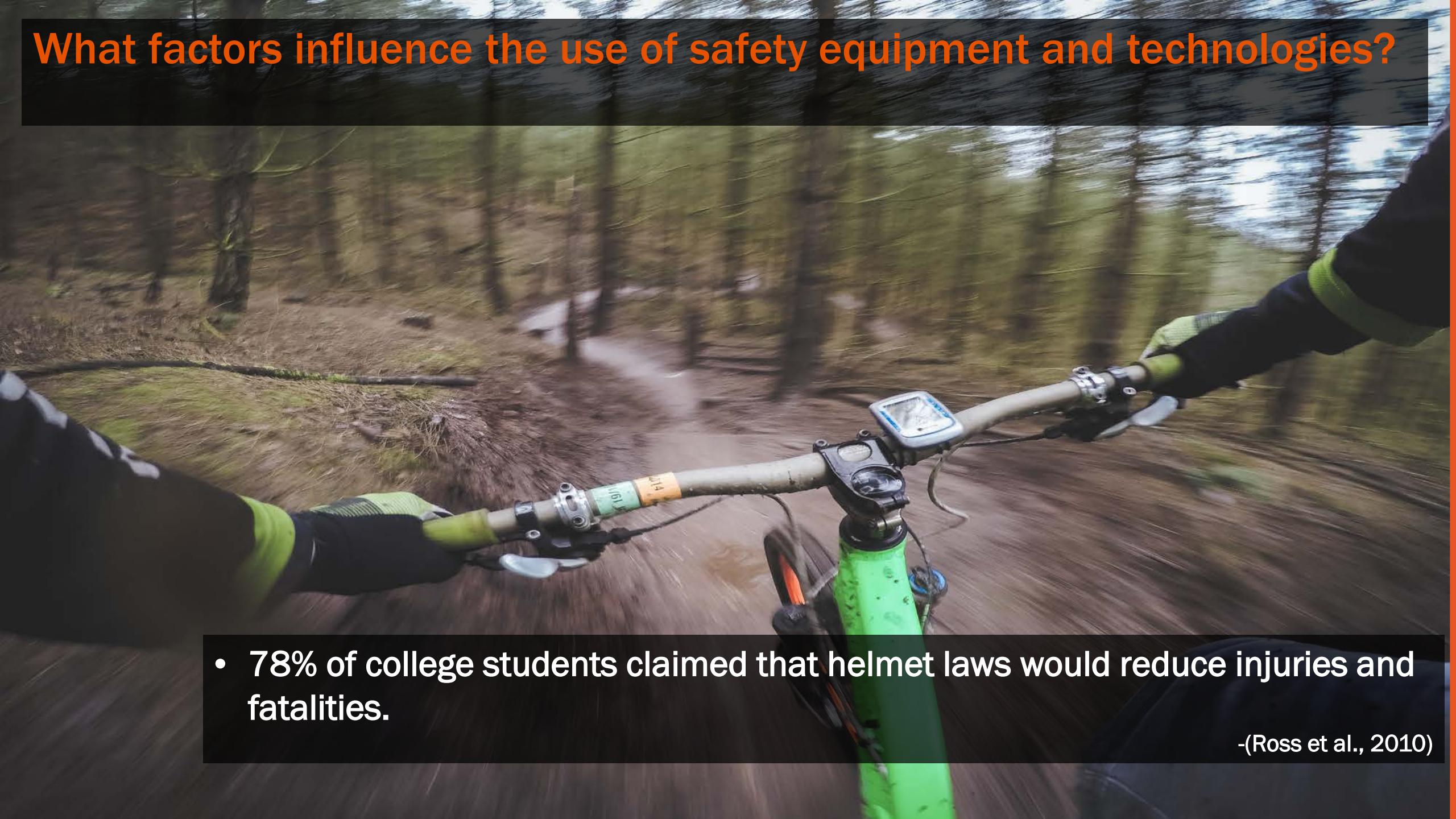
What factors influence the use and implementation of proximity detections systems for mobile machines (mobile PDSs) in underground coal mines?

What factors influence the use of safety equipment and technologies?

- Bicycle helmets can prevent traumatic brain injury.
- 26,000 bicycle-related child and teen injuries result in traumatic brain injury.
- Less than half of Americans wear bicycle helmets.

-(CDC, Head Injuries and Bicycle Safety, 2015)

What factors influence the use of safety equipment and technologies?



- 78% of college students claimed that helmet laws would reduce injuries and fatalities.

-(Ross et al., 2010)

What percentage of the college students reported wearing a bicycle helmet?

A.) 82%
B.) 62%
C.) 22%
D.) 12%

- 78% of college students claimed that helmet laws would reduce injuries and fatalities.

-(Ross et al., 2010)

What percentage of the college students reported wearing a bicycle helmet?

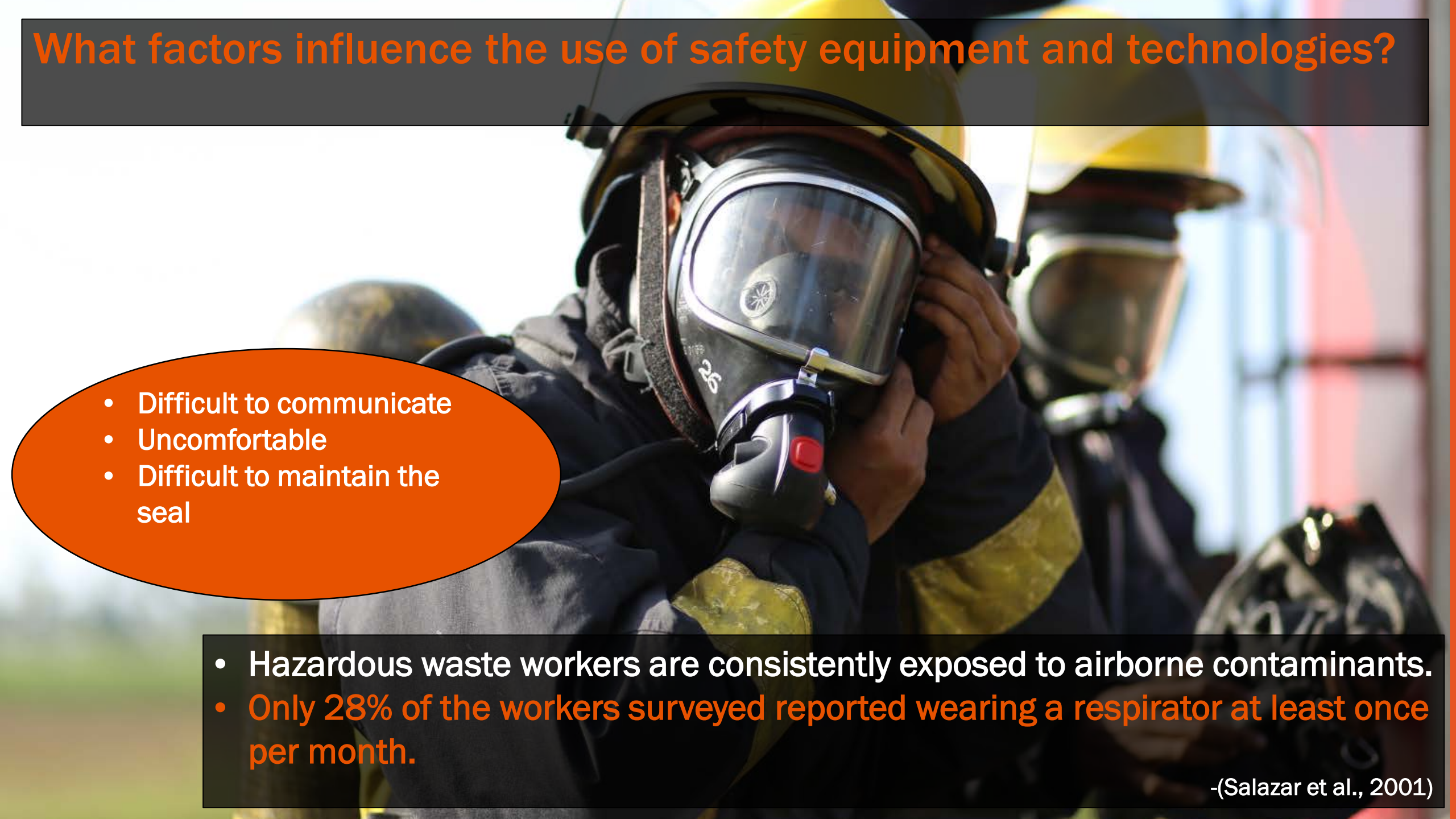
A.) 82%
B.) 62%
C.) 22%
D.) 12%

- Didn't ride enough
- Don't own one
- Don't want to
- Too uncomfortable

- 78% of college students claimed that helmet laws would reduce injuries and fatalities.

-(Ross et al., 2010)

What factors influence the use of safety equipment and technologies?

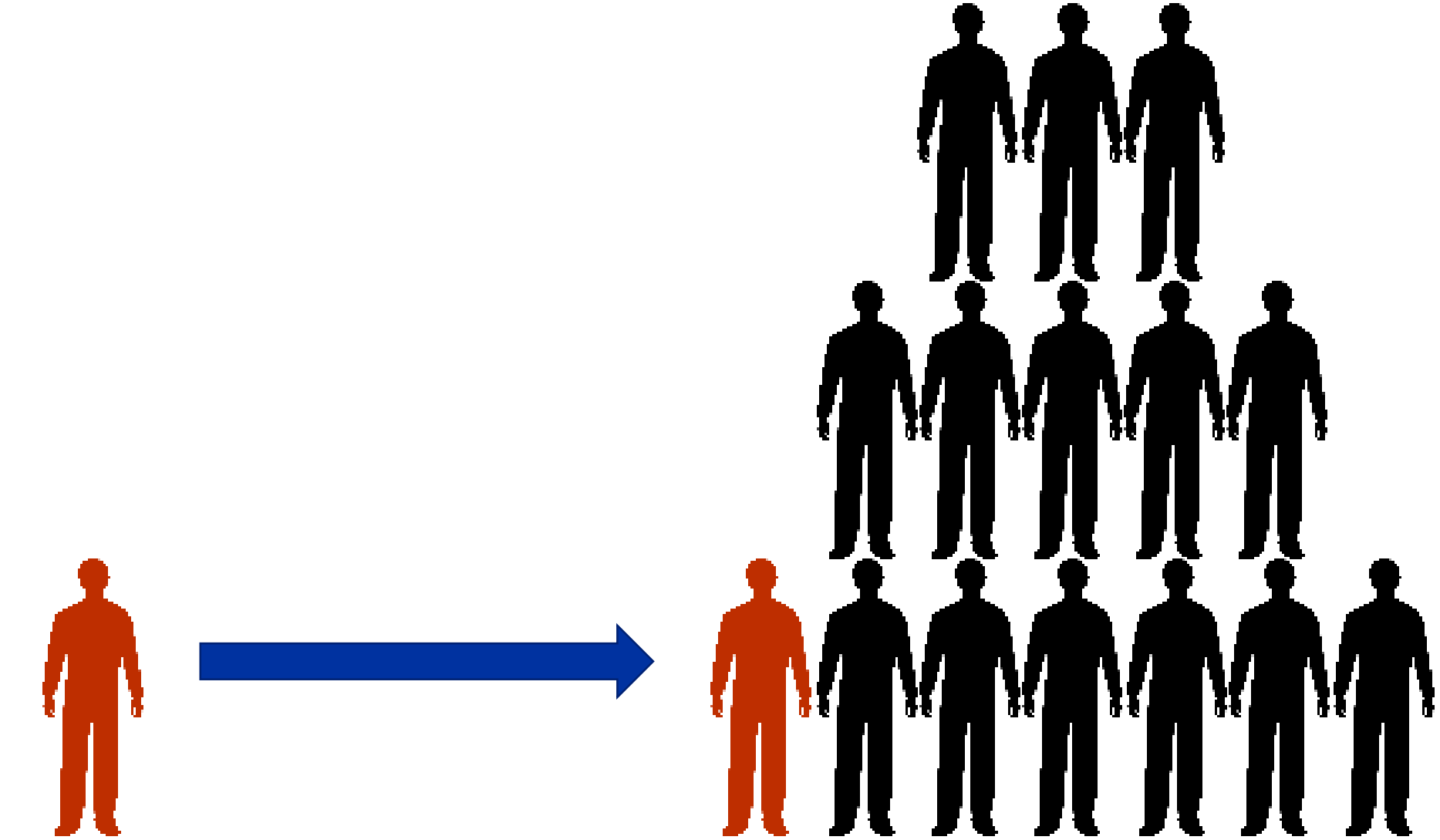


- Difficult to communicate
- Uncomfortable
- Difficult to maintain the seal

- Hazardous waste workers are consistently exposed to airborne contaminants.
- Only 28% of the workers surveyed reported wearing a respirator at least once per month.

-(Salazar et al., 2001)

Past research has shown that individuals can influence organizational safety performance



- Griffin & Neal, 2000

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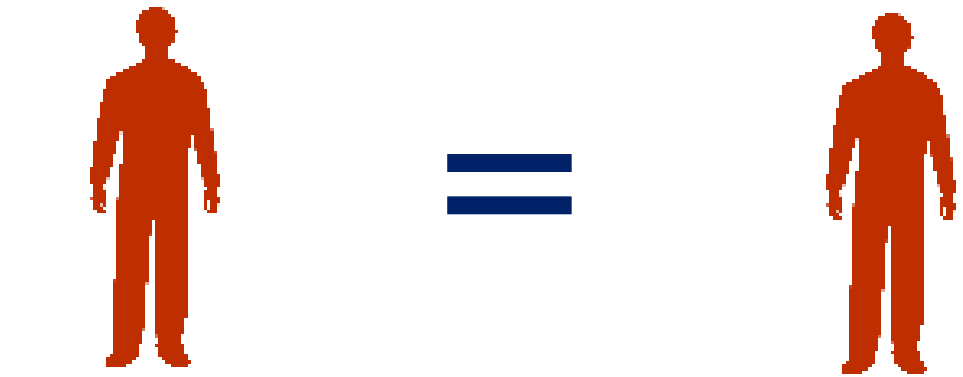
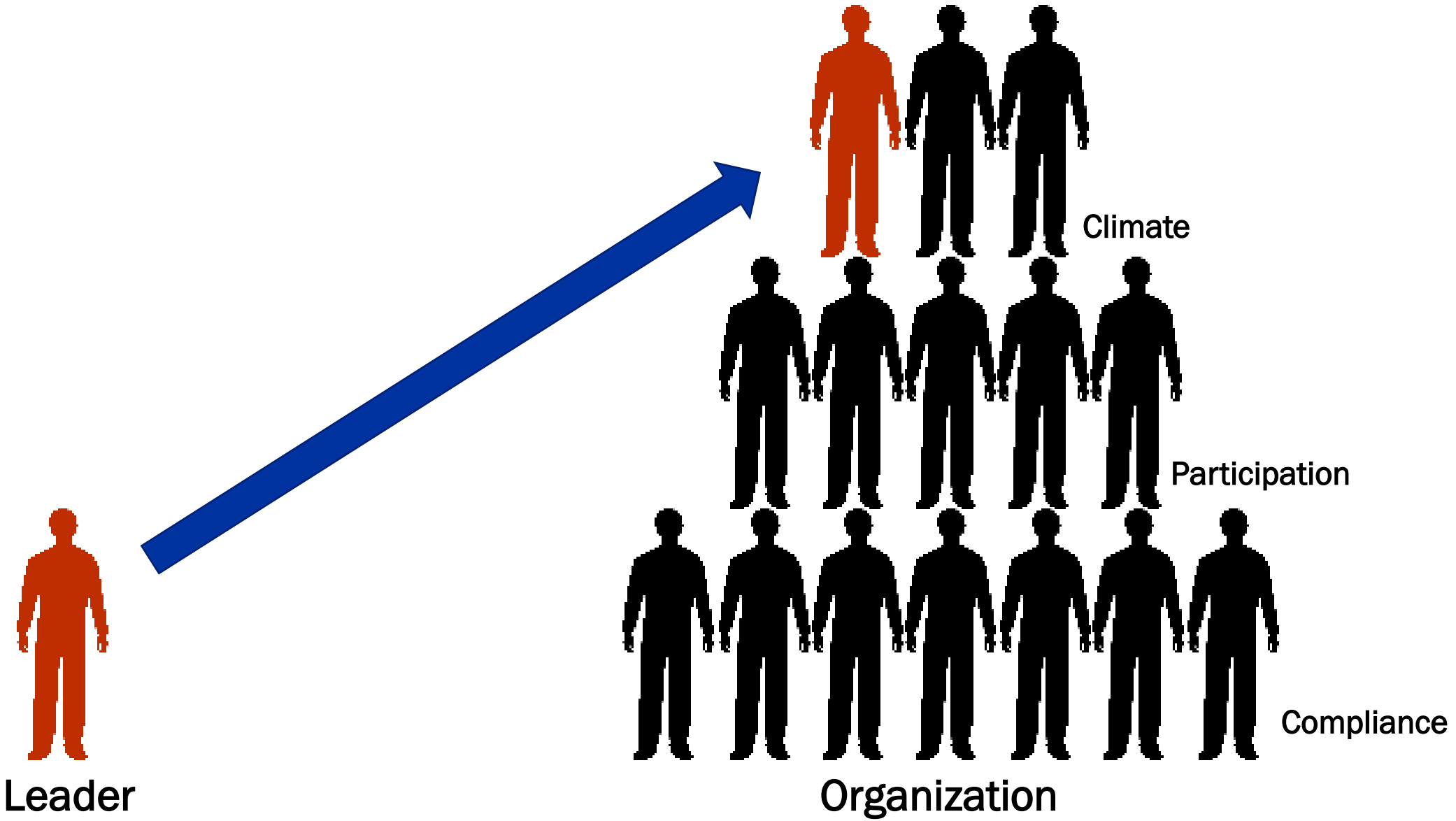
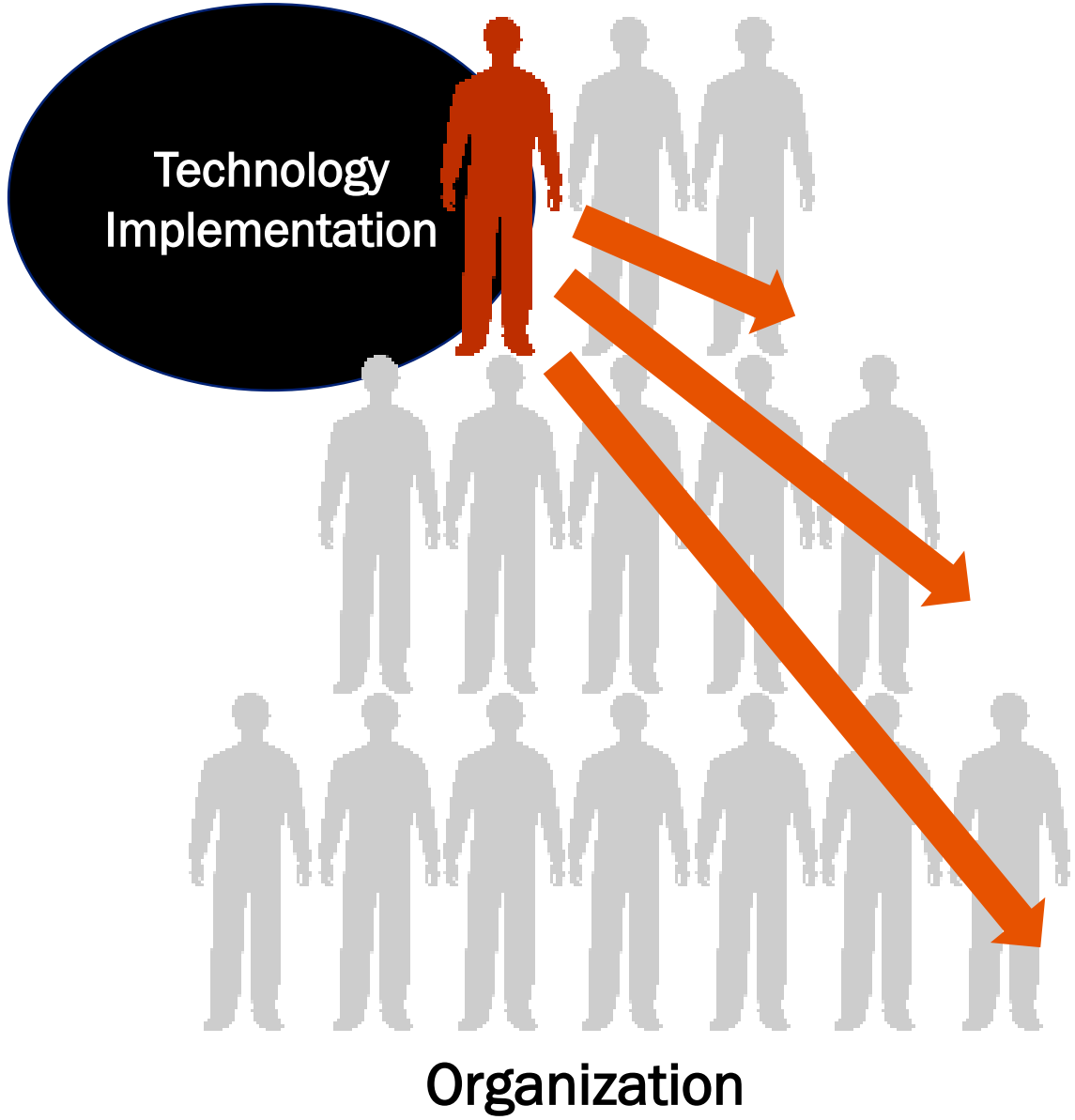


Past research has shown that leaders can influence organizational safety performance



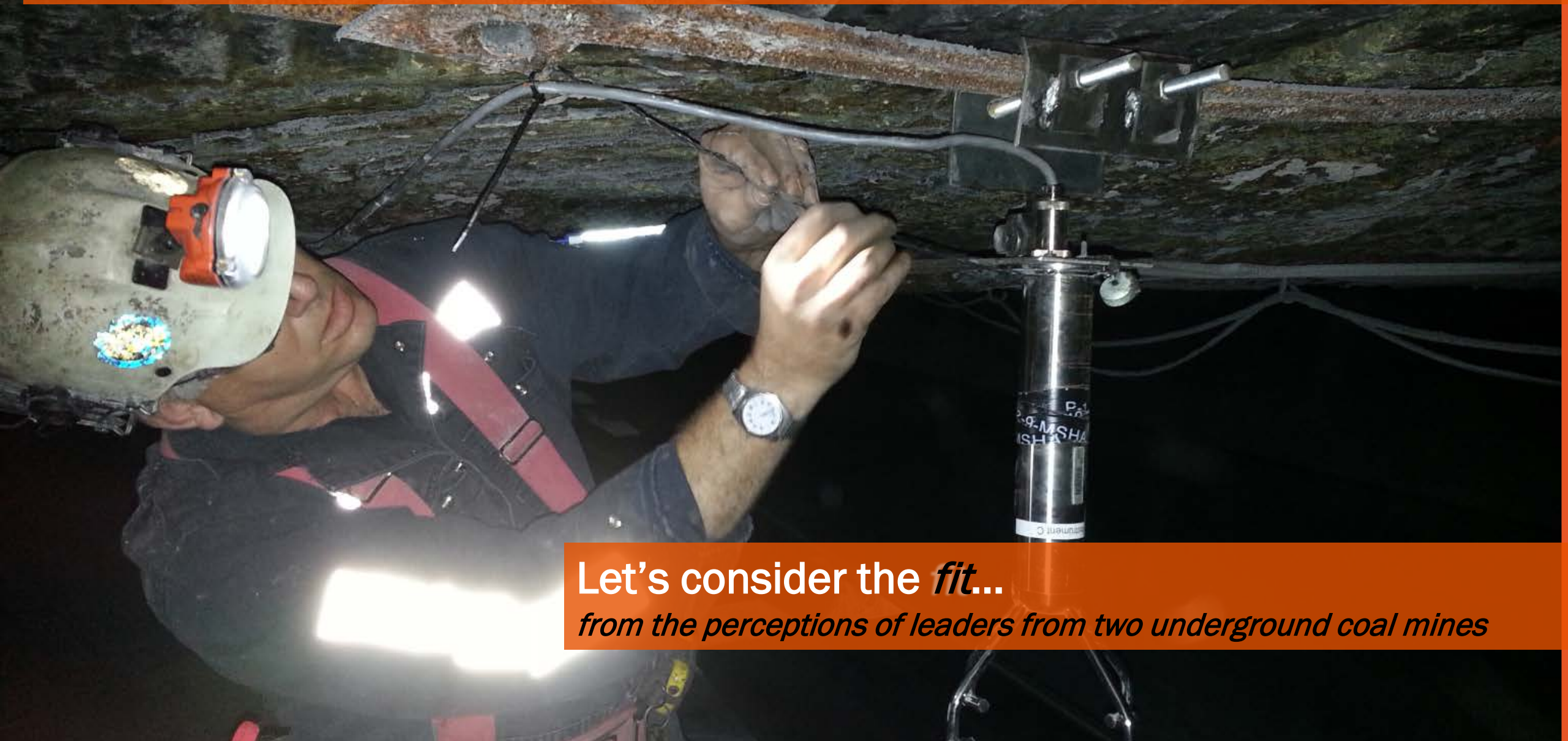
- Griffin & Hu, 2013; Mullen & Kelloway, 2009

Past research has shown that leaders can influence technology adoption and integration



- Ingebrigtsen et al., 2014; Anderson & Dexter, 2005; Russell & Hoag, 2004

What factors influence the use and implementation of mobile PDSs in underground coal mines?



Let's consider the *fit*...

from the perceptions of leaders from two underground coal mines

Proximity detection systems for mobile machines (mobile PDSs)

An automated technology designed to prevent machine-human collisions.

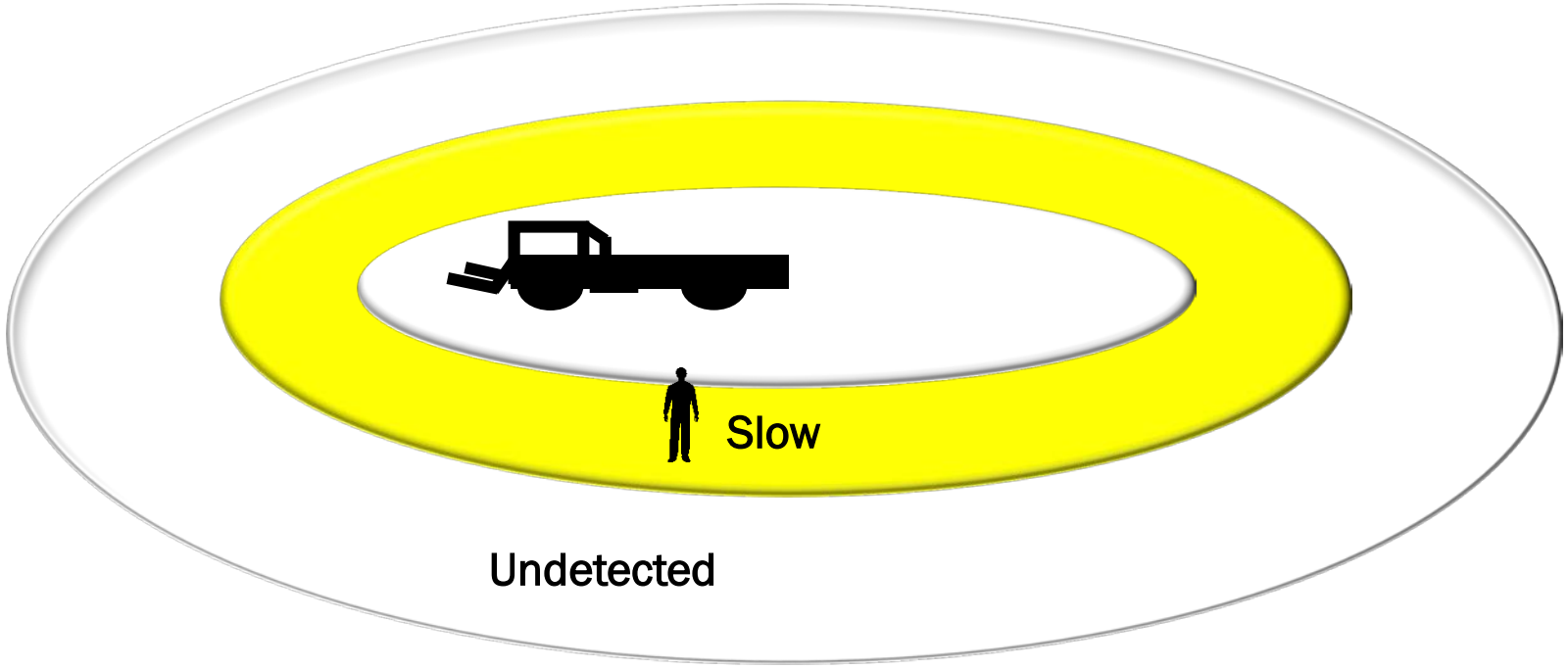
Mobile PDSs are installed on…

- Coal hauling machines
  - Continuous haulage systems
  - Shuttle cars
  - Ram cars
- Scoops

Proximity detection systems (PDSs) for mobile machines

When a worker is in an established warning or shutdown zone…

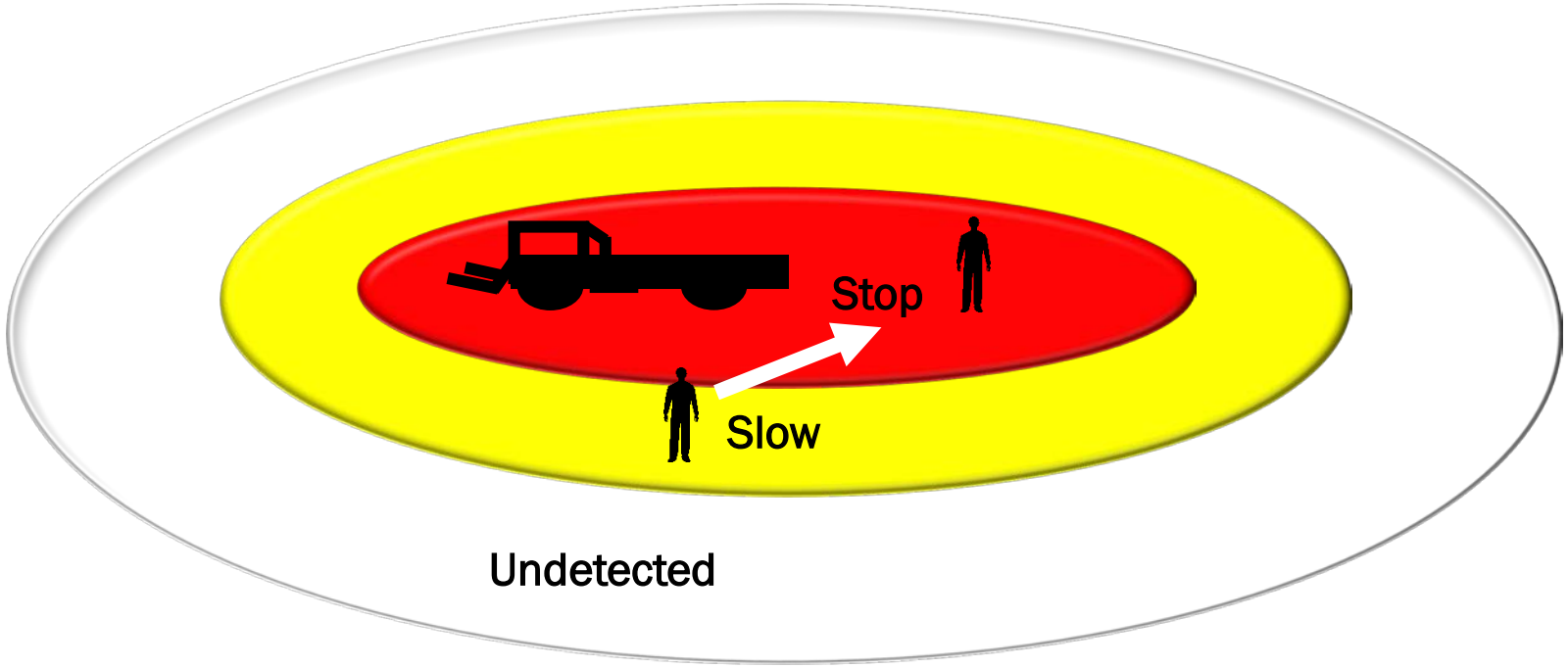
- Worker is alerted by their miner wearable component (MWC)



Proximity detection systems (PDSs) for mobile machines

When a worker is in an established warning or shutdown zone…

- Worker is alerted their miner wearable component (MWC)
- Mobile machine is slowed or disabled



Currently, the fit between mobile PDSs and underground coal mining is unclear

Could prevent 70 injuries and 15 fatalities over next 10 years

-(MSHA, 2015)

- Mineworker fatally injured after disabling PDS on a continuous mining machine

-(MSHA, 2017)

- Concerns about electromagnetic interference, respirable dust sampling, nuisance trips driving the “wrong behavior”

-SNL Energy Report (Taylor, 2018)

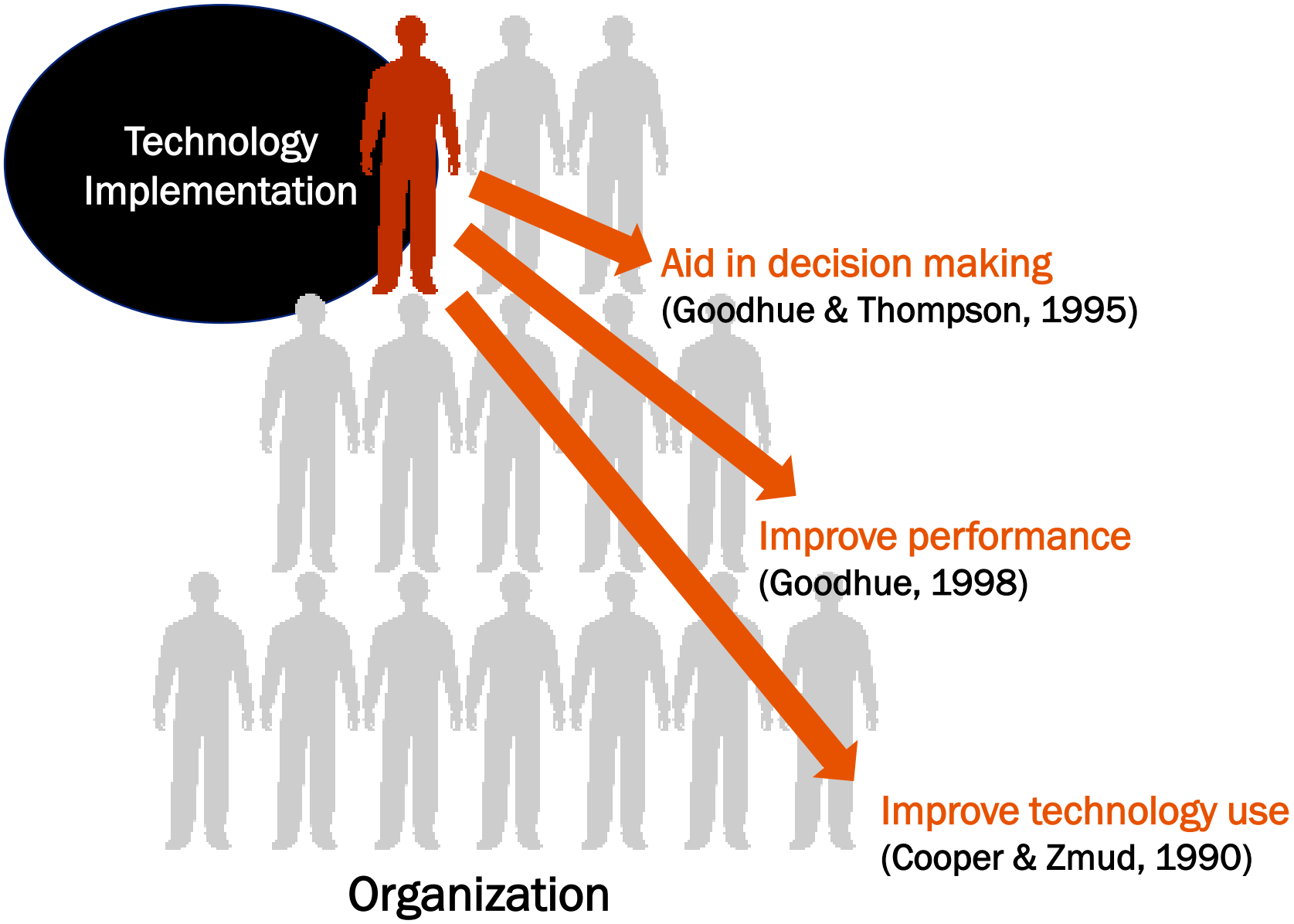
Task-technology fit assumes that the system will aid miners in safely completing job tasks

Theoretical Assumptions:

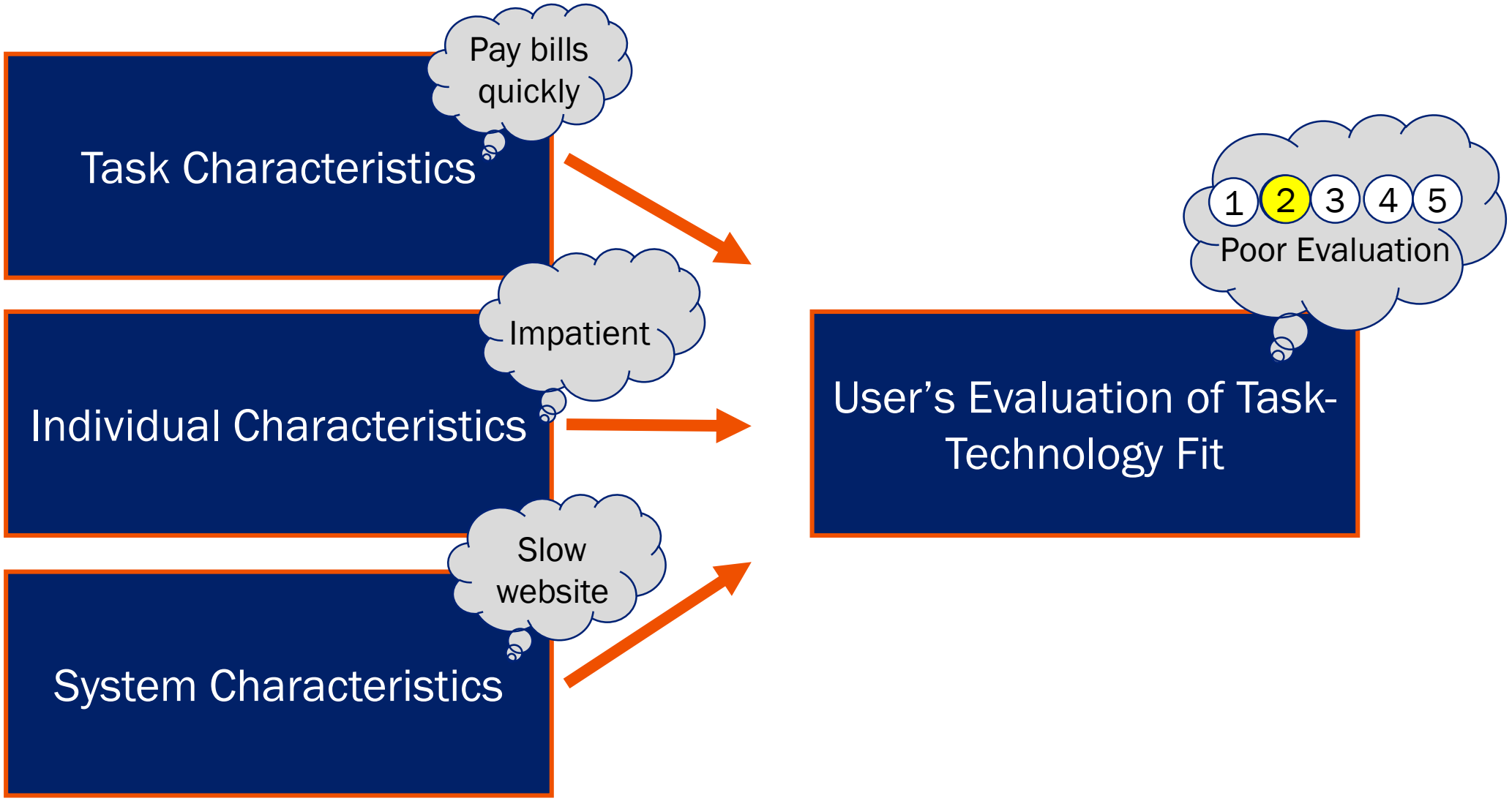
- System will support workers in safely completing tasks
- Degree of usefulness will be conveyed through users' assessments of the system

- Goodhue, 1998; Goodhue & Thompson, 1995

Task-technology fit has been used to…



Task-Technology Fit



- Goodhue, 1998; Goodhue & Thompson, 1995

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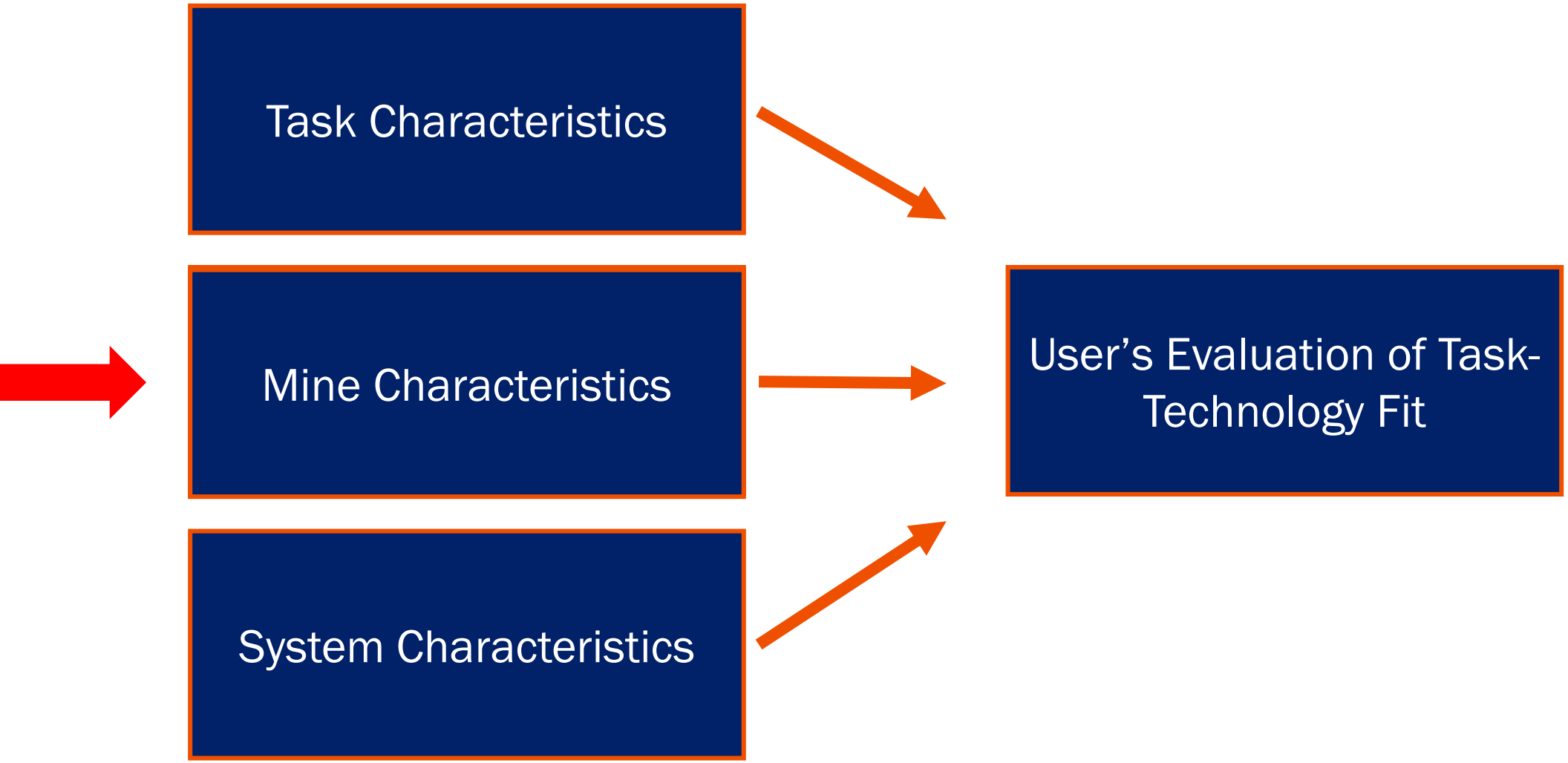


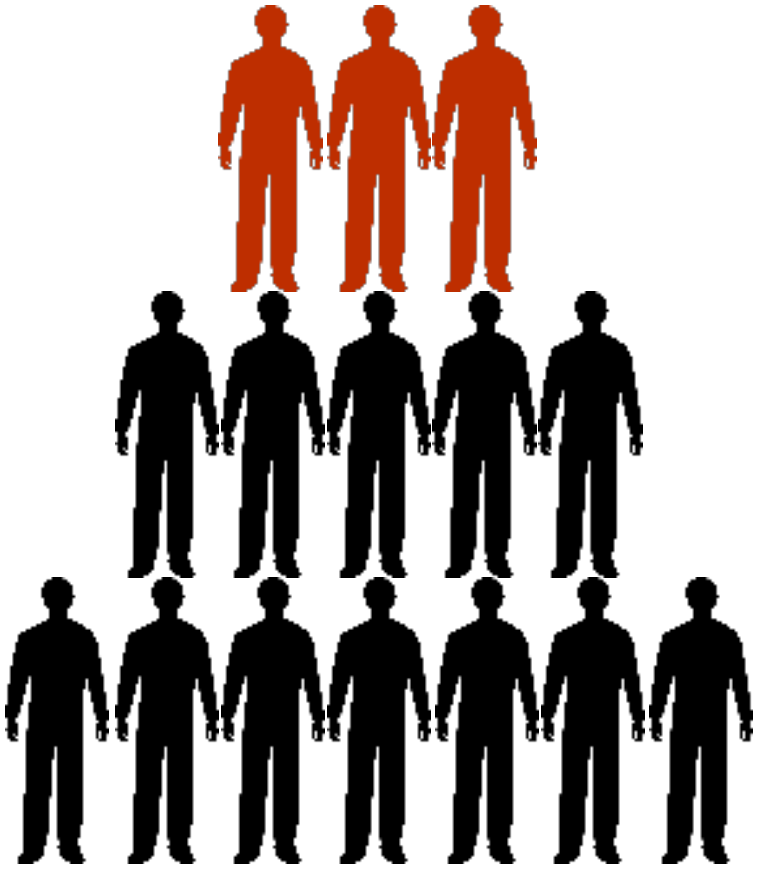
- Goodhue, 1998; Goodhue & Thompson, 1995

Focus groups and surveys were used to collect data

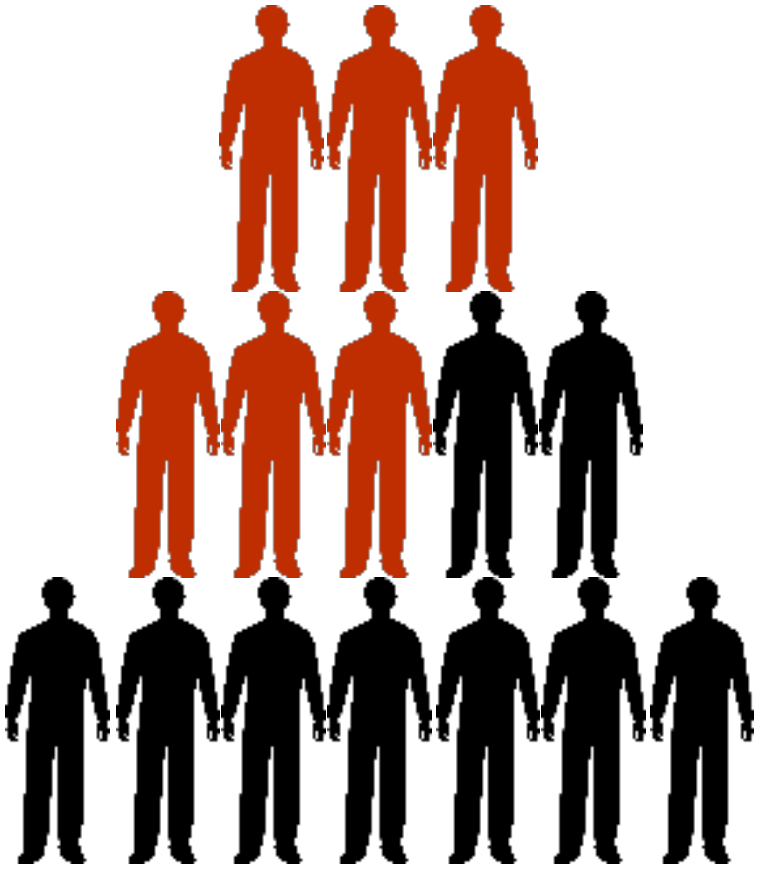
Study Design:

- Mixed-methods approach
- Conducted two, 60-90 minute, focus groups
- Included leaders from underground coal mines currently using mobile PDSs
- Participants individually completed surveys (prior to focus group)

Nine leaders from two different underground coal mines participated in the study

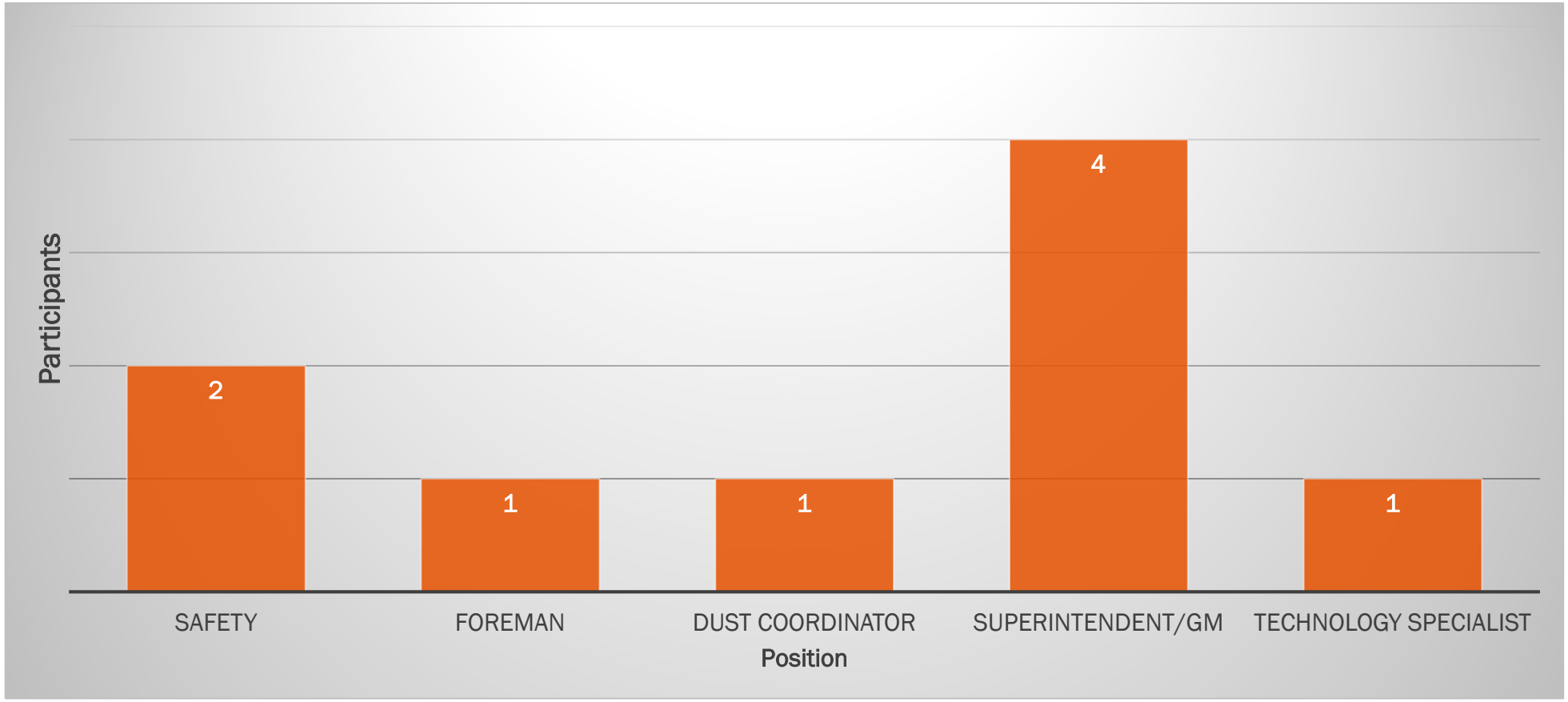


Organization



Organization

Participants were in leadership roles and involved in the implementation of the PDS



Participants were experienced miners

Years of Experience	Frequency	Years at Mine	Frequency	Years in Position	Frequency	Knowledge of Mobile PDS	Frequency
Less than 1	0	Less than 1	0	Less than 1	2	None	0
1 – 5	0	1 – 5	1	1 – 5	4	Basic	1
6 – 10	2	6 – 10	2	6 – 10	2	Practical	7
11 – 15	1	11 – 15	1	11 – 15	0	Expert	1
More than 15	**6**	More than 15	5	More than 15	1	Total	9
Total	9	Total	9	Total	9		

Age (yrs)			
Minimum	Maximum	Mean (M)	Standard Deviation (SD)
29	65	48.89	12.82

Participants had seniority at their mines

Years of Experience	Frequency	Years at Mine	Frequency	Years in Position	Frequency	Knowledge of Mobile PDS	Frequency
Less than 1	0	Less than 1	0	Less than 1	2	None	0
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However, most of the participants had less than 6 years in their positions

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Age (yrs)			
Minimum	Maximum	Mean (M)	Standard Deviation (SD)
29	65	48.89	12.82

Participants had practical knowledge of PDSs

Years of Experience	Frequency	Years at Mine	Frequency	Years in Position	Frequency	Knowledge of Mobile PDS	Frequency
Less than 1	0	Less than 1	0	Less than 1	2	None	0
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The average age of participants was 49 years old

Years of Experience	Frequency	Years at Mine	Frequency	Years in Position	Frequency	Knowledge of Mobile PDS	Frequency
Less than 1	0	Less than 1	0	Less than 1	2	None	0
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Age (yrs)			
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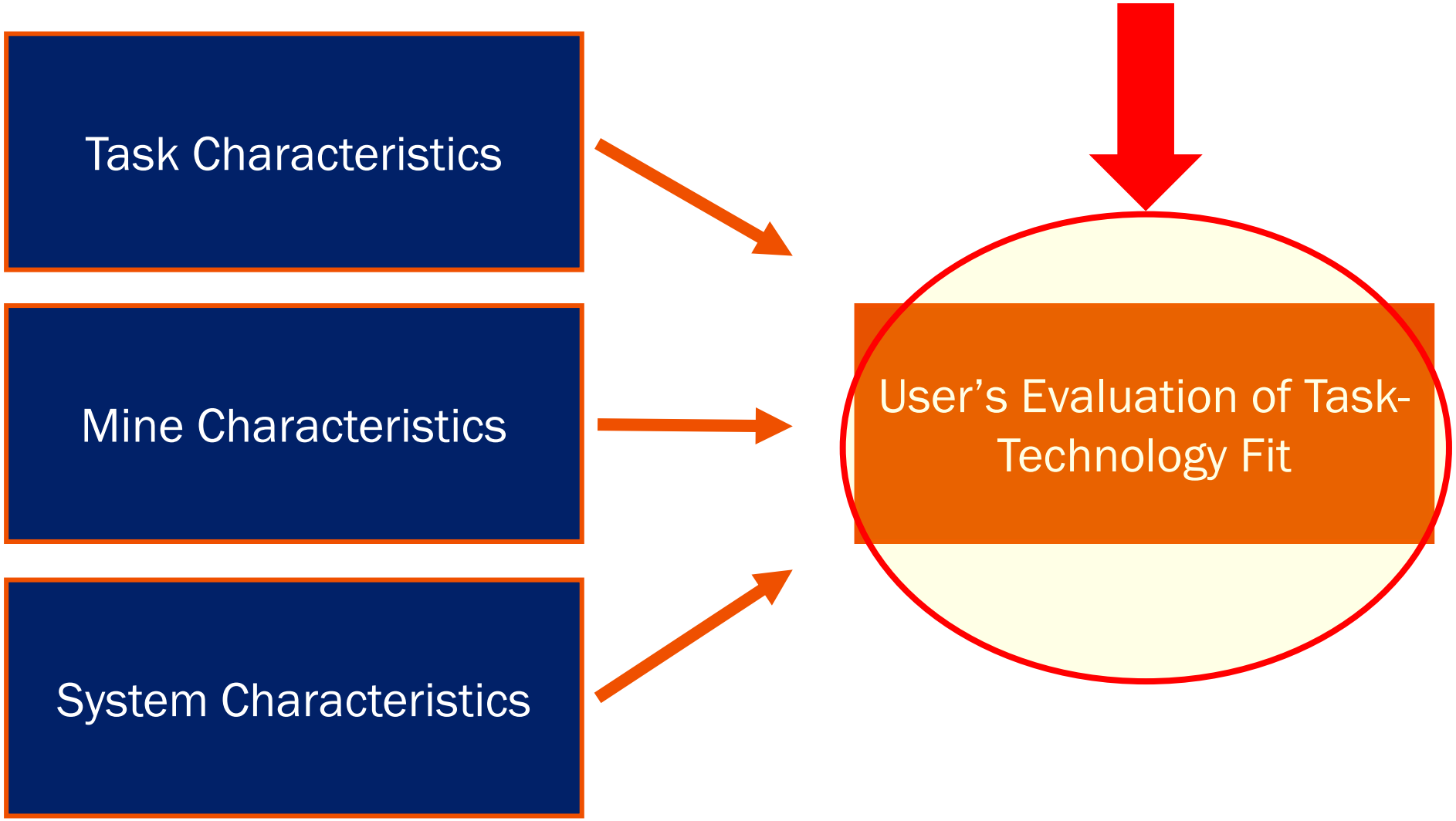
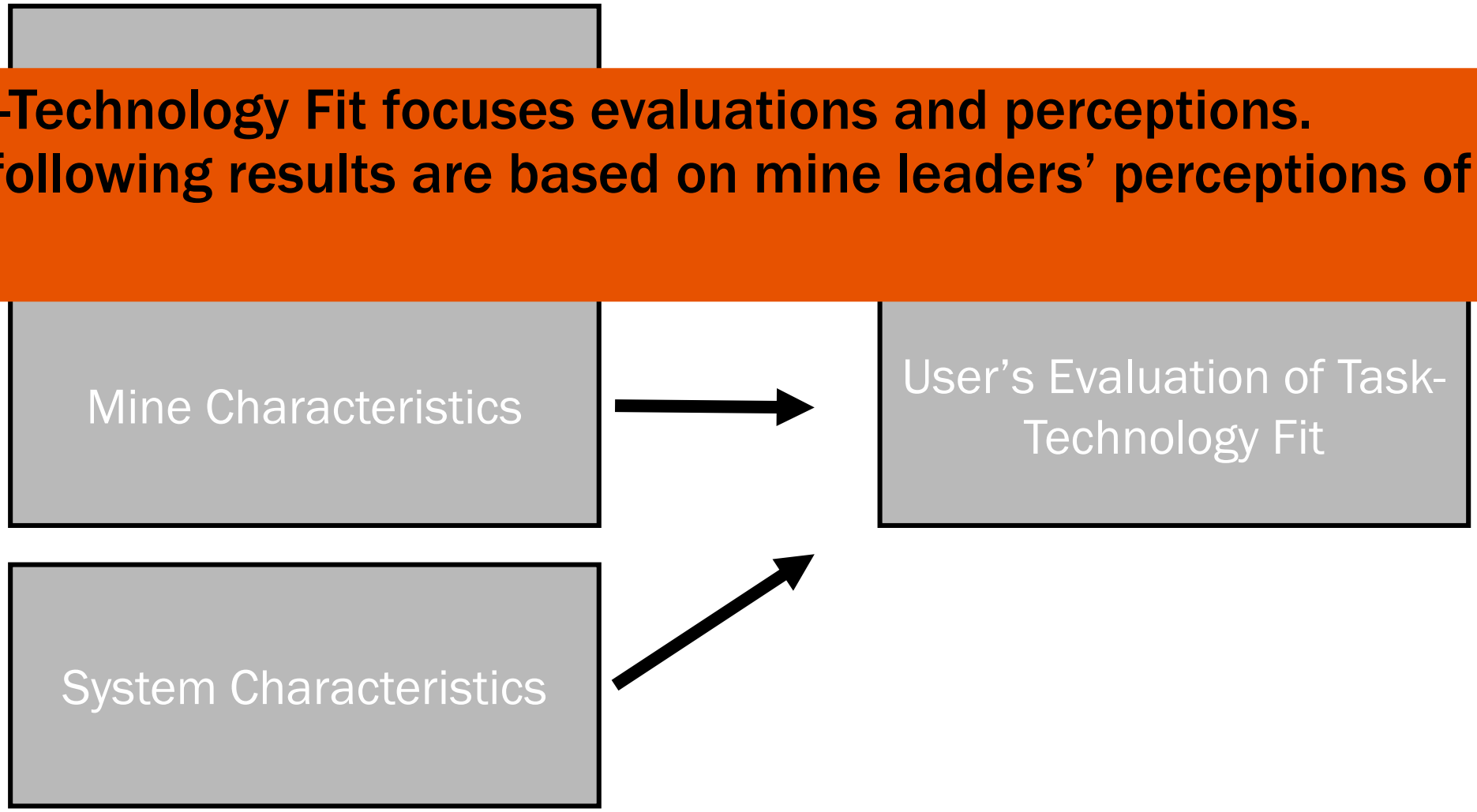
Task-Technology Fit



- Goodhue, 1998; Goodhue & Thompson, 1995

Task-Technology Fit

Task-Technology Fit focuses evaluations and perceptions.
The following results are based on mine leaders' perceptions of their mobile PDS.



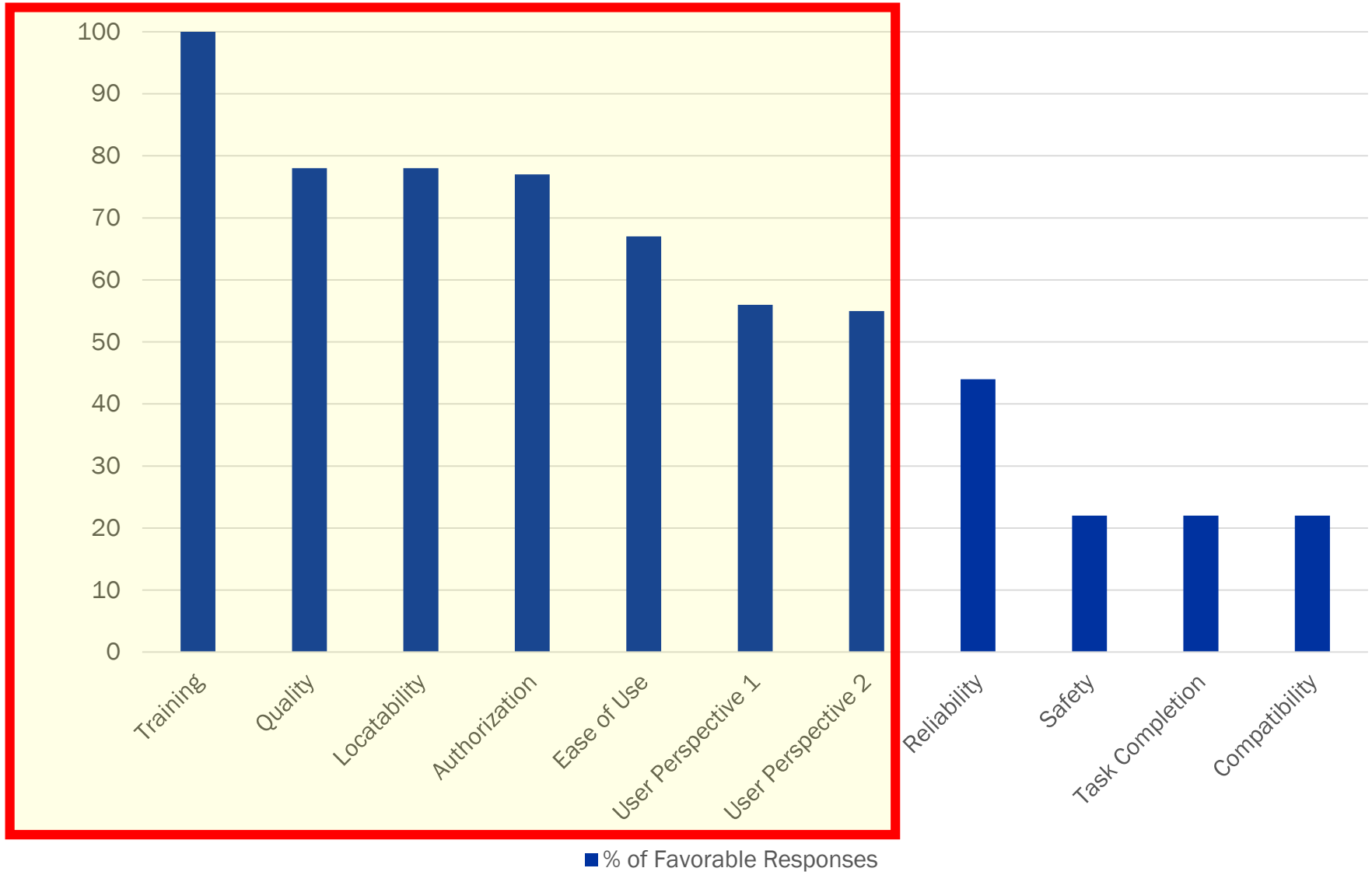
- Goodhue, 1998; Goodhue & Thompson, 1995

The dimensions of Task-Technology Fit used in the pilot study

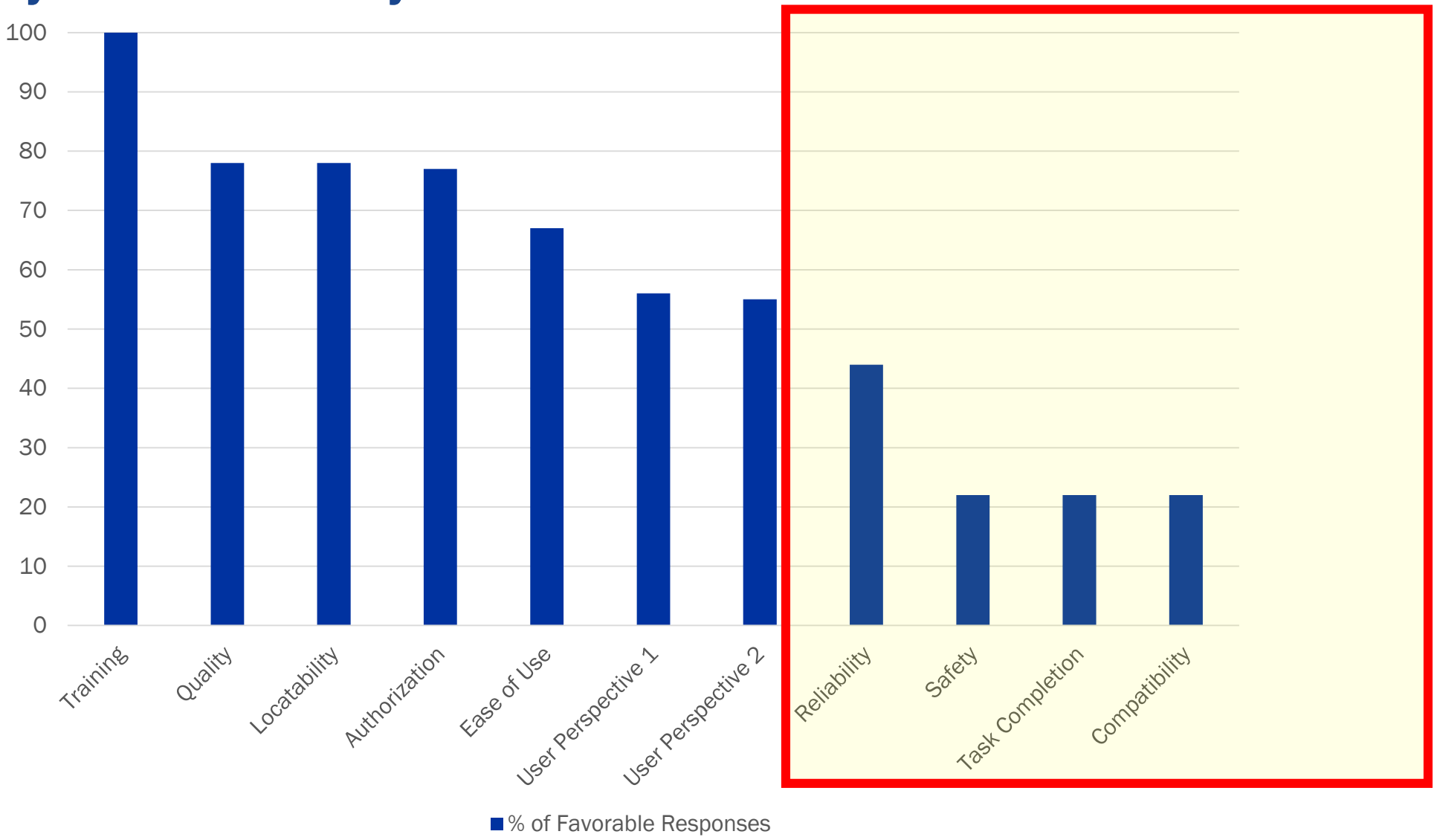
Original (Goodhue & Thompson, 1995)	Pilot Study
Compatibility	Compatibility
Production timeliness	Task completion
Locatability	Locatability
Information system's (IS's) relationship with users	User perspective
Training and ease of use	Training and ease of use
Data quality	Quality
System reliability	System reliability
Authorization	Authorization
	Safety



More than half of the mine leaders gave favorable ratings for 7 of the 11 survey questions



Mine leaders rated reliability, safety, task completion, and compatibility less favorably



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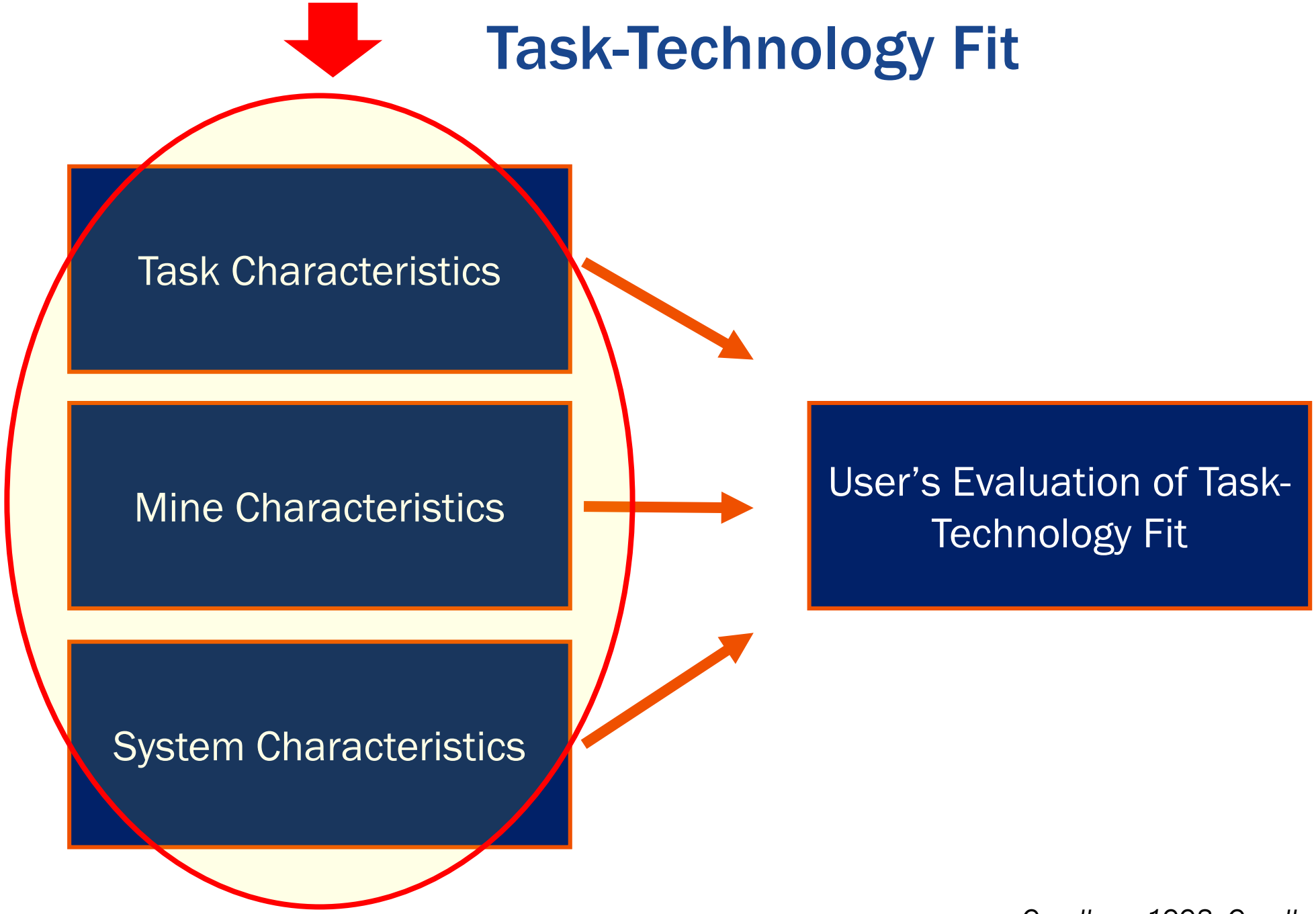

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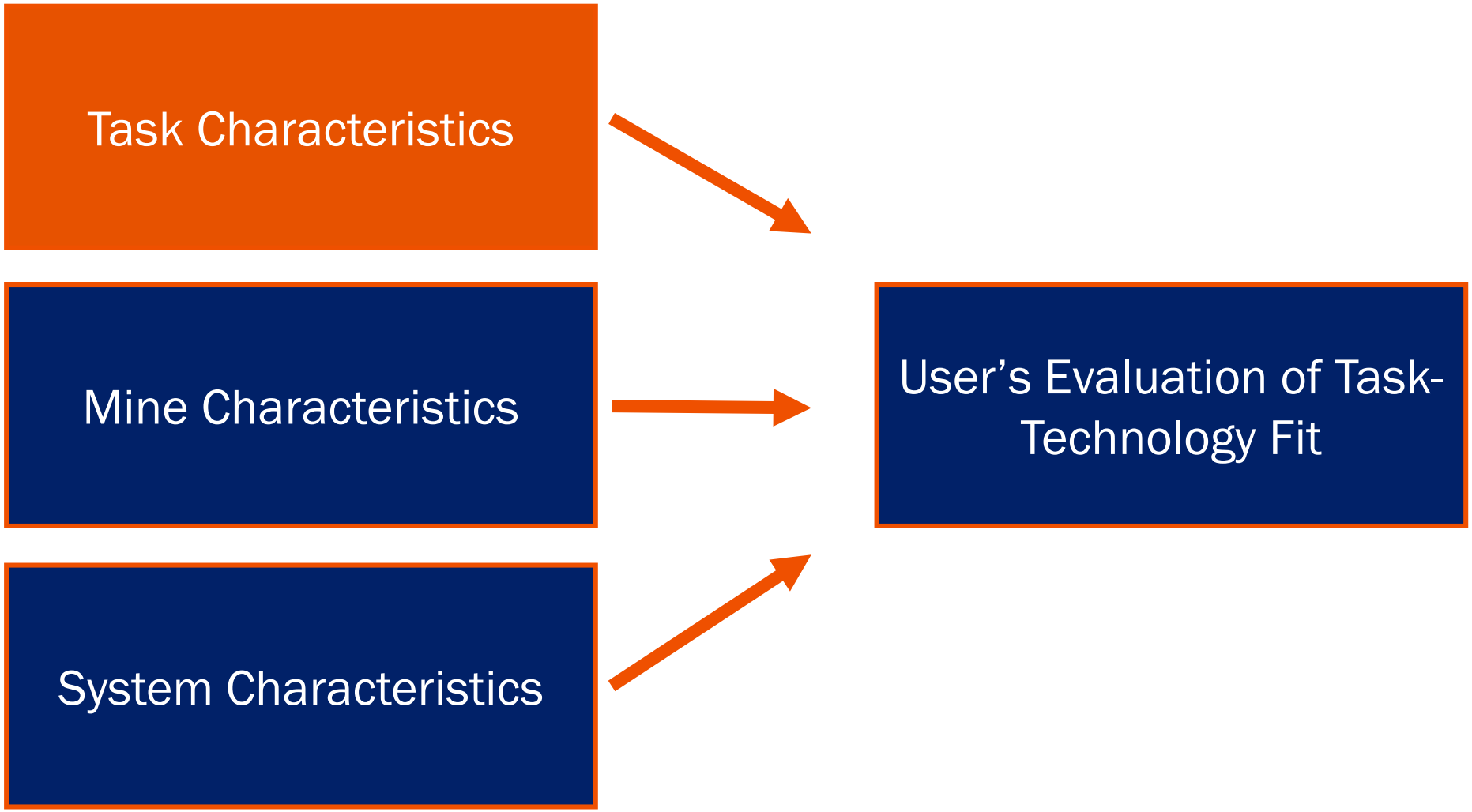
Task-Technology Fit



- Goodhue, 1998; Goodhue & Thompson, 1995

Mobile PDSs can improve situational awareness and decrease risk

Task Characteristics	Positive Influence	Negative Influence
Working around mobile machines	"The system makes you think. Makes you stay further away—eliminating risk" (*Mine B*)	"[A mobile PDS] makes things harder and less safe." (*Mine B*).
Operating mobile machines	*N/A*	"Once loaded and on any type of grade, it didn't have enough power to pull away" (*Mine A*).
Maintaining mobile machines	*N/A*	"The machines were not built for these systems…and they just get torn off…" (*Mine A*).
Setting up the section	*N/A*	"With mobile and mesh, you have to hang the cable at a 45-degree or any angle in order to not magnify or distort the signal" (*Mine B*).
Visiting the section	*N/A*	"Proximity inhibits safety inspections (Mine B)."

Mobile machines may not be able to pull away when loaded

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It may be challenging to maintain PDSs on mobile machines

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Mobile PDSs may change section set up and downshift work

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Visiting the section	*N/A*	"Proximity inhibits safety inspections (Mine B)."

Mobile PDSs may make it difficult to visit the section or conduct safety inspections

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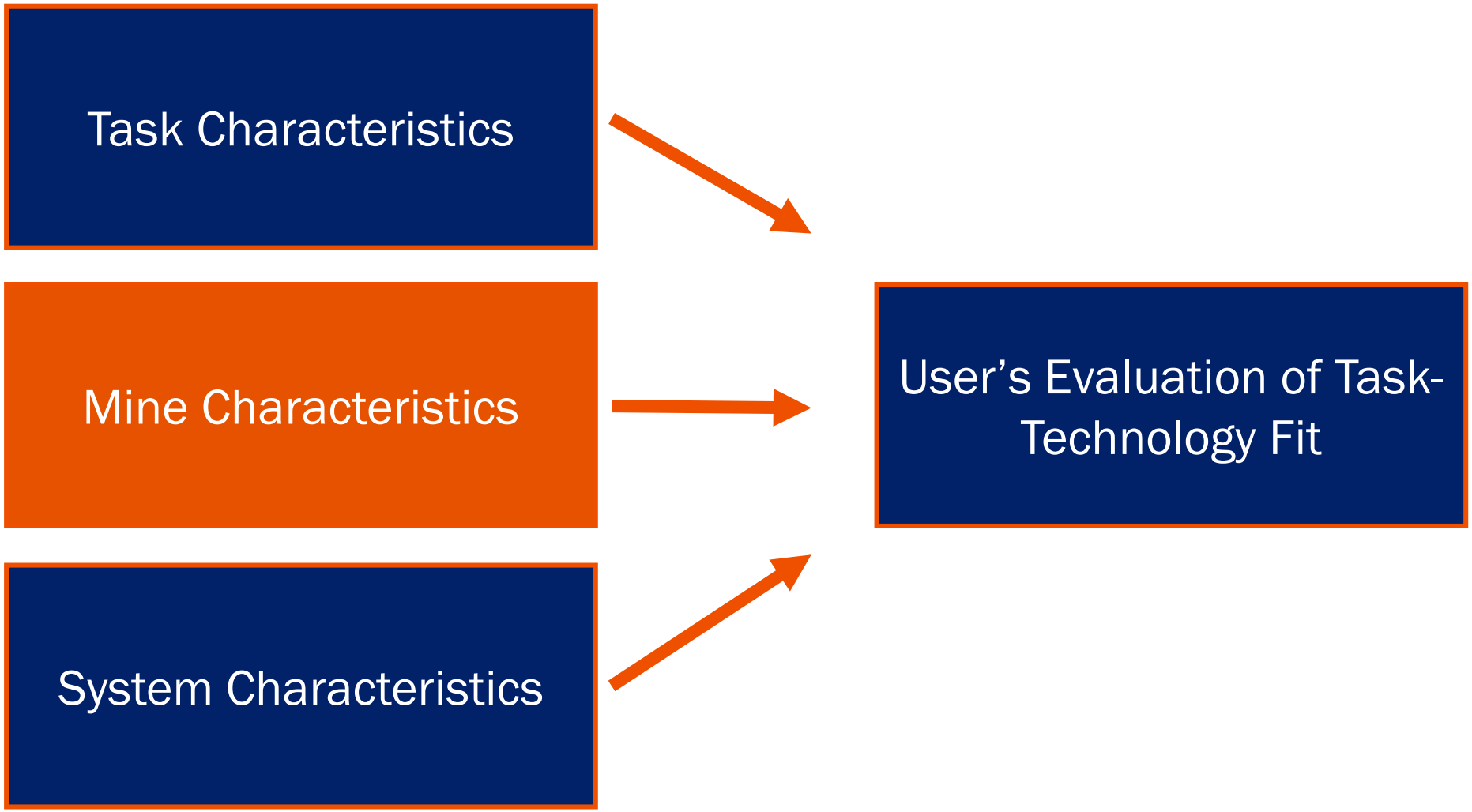
Task-Technology Fit



- Goodhue, 1998; Goodhue & Thompson, 1995

Mineworkers, especially mechanics, need mobile PDS training

Mine Characteristics	Positive Influence	Negative Influence
Training	"Everyone that works with proximity had 10-20 hours of hands-on training" (*Mine B*).	"Untrained mechanics have tried and caused more problems" (Mine B).
Culture	"Have to have safety culture…not everyone has a GM [general manager] that says they want to use it" (*Mine B*).	"A good example is the recent fatality where the miner took off the locator…At that location there wasn't a culture to keep the [MWC] on. Here, culture requires it" (Mine B).
Conditions	"It is easier at our mine because it is consistent and doesn't change" (*Mine B*).	"The orange cases created static…because of the humidity level" (Mine B).
Resources	"Because we have spare equipment, they don't feel the pressure to fix it, if it breaks on swing shift and we don't have a mechanic on shift" (*Mine B*).	"But the extra machine increases the maintenance cost, increases the time to perform permissibility checks, and overall increases the manpower…" (*Mine B*).

The mine's existing safety culture can influence mobile PDS implementation

Mine Characteristics	Positive Influence	Negative Influence
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Mine conditions such as seam height, humidity, use of steel mesh, and soft floors can influence mobile PDS implementation

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Successful mobile PDS implementation requires dedicated mine resources

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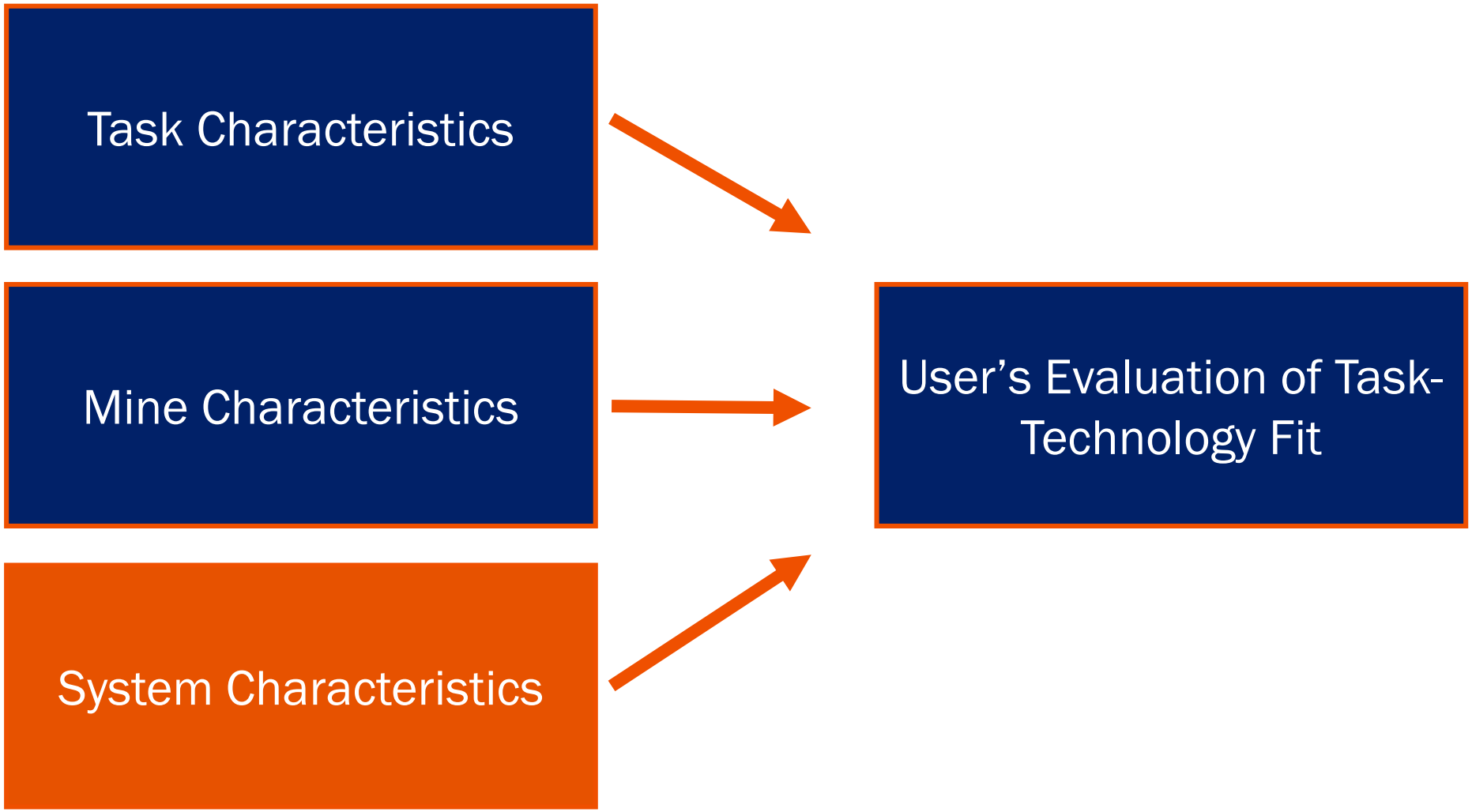

- Goodhue, 1998; Goodhue & Thompson, 1995

Mobile PDSs can be reliable, but electromagnetic interference can create performance issues

System Characteristics	Positive Influence	Negative Influence
Performance	"The proximity system is reliable for everyday use. Now that we have worked all the bugs out, it is more reliable" (*Mine B*).	"We've incorporated this SOS signal every time it gets interference, it beeps from the time you drop in the mine to the time you get back out of the mine" (*Mine A*).
Usability and system features	"It is easy to see. If you shutdown there is a screen with the locator number that is shutting you down" (*Mine B*).	"This [MWC] and proximity and radio there is not enough room on these guys belts" (Mine A).
Support	"Every time I've called our [manufacturer's name] rep, he has answered the phone…and we've had him out on the property numerous times" (*Mine A*).	"We don't have the research and development here to manufacture a brand new prox and go through the procedure" (*Mine A*).
Requirements	"It all has to do with the way it is maintained as well" (Mine A).	"I mean several of them do get torn up, but we've hired so many people in the last two years…I would say that…I know I've ordered close to 500" (*Mine A*).

The MWC can be easy to use, but there may be challenges with wearability

System Characteristics	Positive Influence	Negative Influence
Performance	"The proximity system is reliable for everyday use. Now that we have worked all the bugs out, it is more reliable" (*Mine B*).	"We've incorporated this SOS signal every time it gets interference, it beeps from the time you drop in the mine to the time you get back out of the mine" (*Mine A*).
Usability and system features	"It is easy to see. If you shutdown there is a screen with the locator number that is shutting you down" (*Mine B*).	"This [MWC] and proximity and radio there is not enough room on these guys belts" (*Mine A*).
Support	"Every time I've called our [manufacturer's name] rep, he has answered the phone…and we've had him out on the property numerous times" (*Mine A*).	"We don't have the research and development here to manufacture a brand new prox and go through the procedure" (*Mine A*).
Requirements	"It all has to do with the way it is maintained as well" (Mine A).	"I mean several of them do get torn up, but we've hired so many people in the last two years…I would say that…I know I've ordered close to 500" (*Mine A*).

Manufacturer/vendor representatives support is helpful. Additional resources may be needed.

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Proper maintenance is required for mobile PDSs to work properly; some requirements may require significant investments

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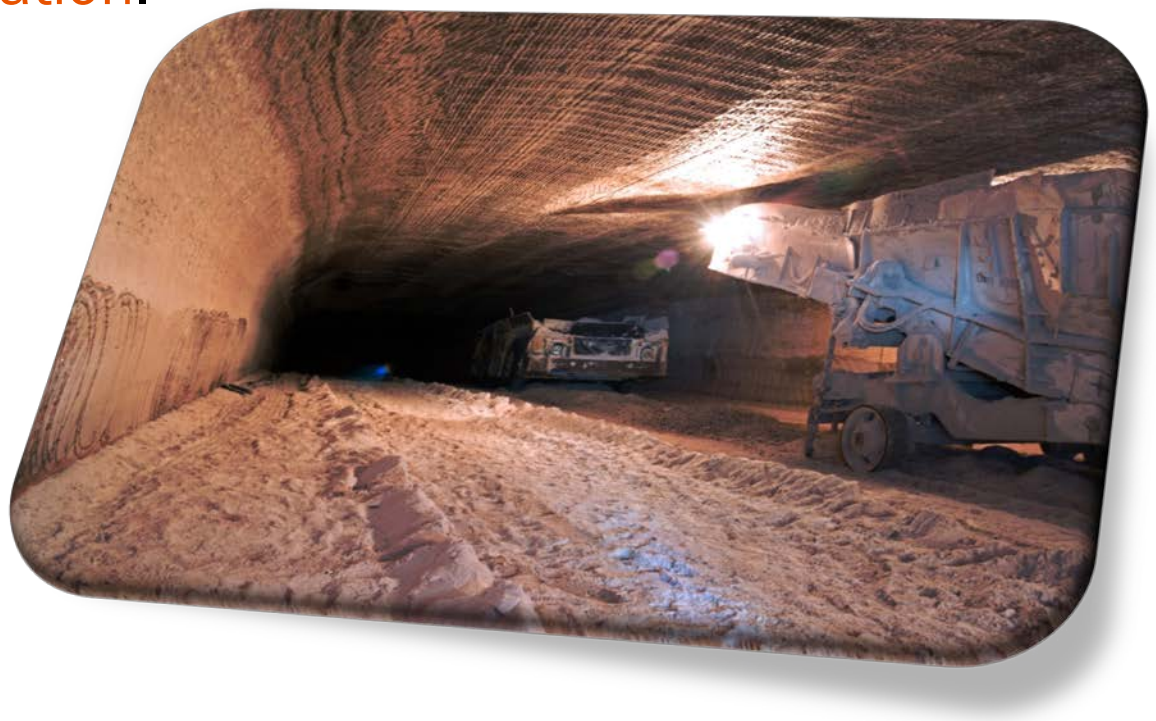
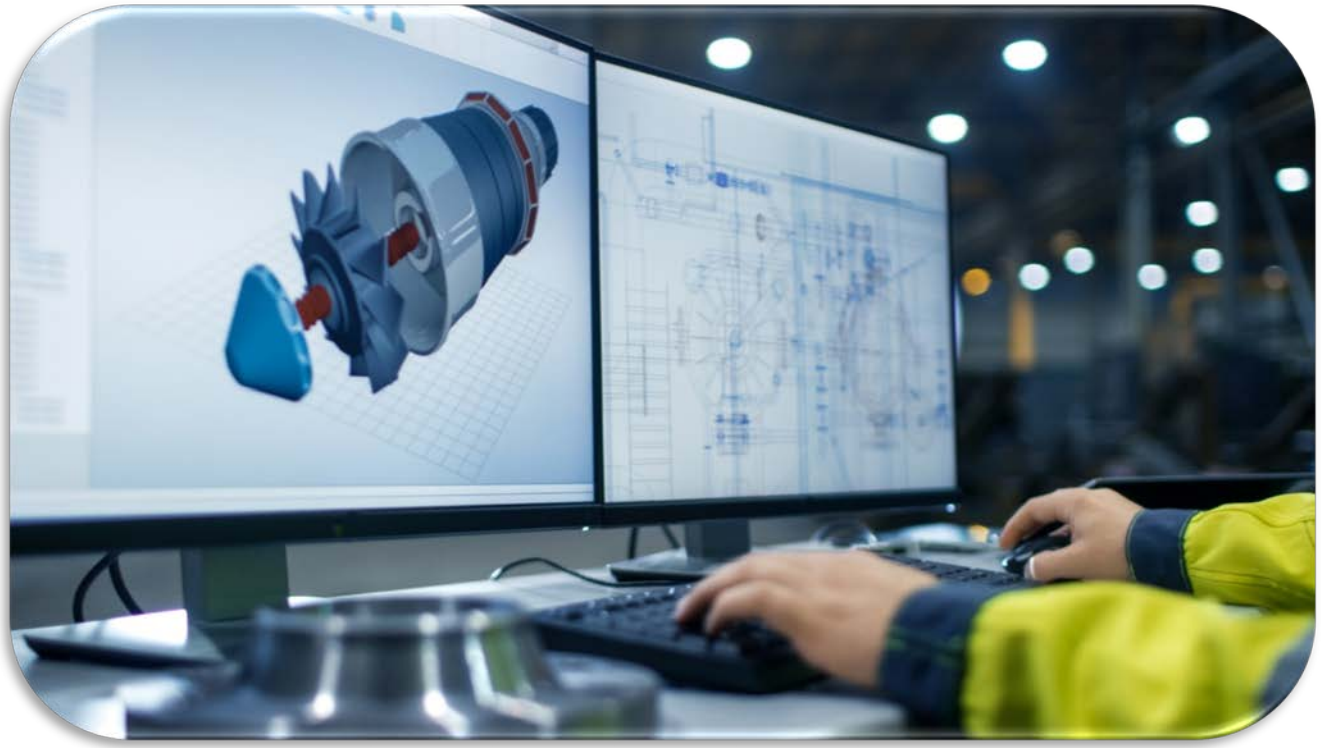
Suggestions for Mine Operators

- Evaluate mine conditions that may pose challenges.
- Identify how a mobile PDS may change specific tasks.
- Develop training programs for workers, especially maintenance workers.
- Assess, secure, and dedicate resources for implementation.
- Evaluate the mine's existing safety culture.
- Identify ways to manage worker frustration.



Suggestions for Researchers and Equipment Designers

- Further identify and address the electromagnetic-interference issues.
- Provide resources and forums for common challenges and best practices.
- Consider ways to improve wearability of the MWC.
- Explore system customization.



Please feel free to contact me with questions or comments

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