Cerrejón

Minería responsable

Evaluation of the design of the shift work in an open pit coal mine using paired comparison methodology

Introduction

To guarantee continuous operation, global mining companies operate 24/7. They therefore design shift work patterns that, while observing safety provisions related to sleep and fatigue issues and complying with national and international law, allow them to operate continuously.

This study was designed to evaluate the impact of the current shift pattern in an open-pit coal mine in northern Colombia in terms of the operation itself as well as its acceptance on the part of employees.

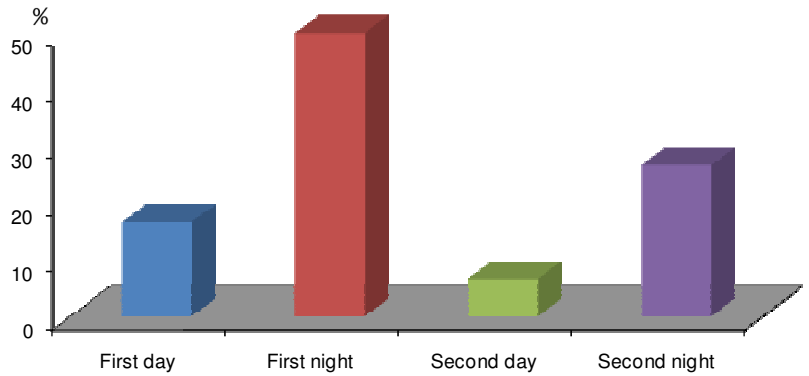
Current shift pattern (12 h/d) 42.5 h / week*

D _ N _ D _ N _ _ _

* 48 h / week (Colombian legislation)

Introduction

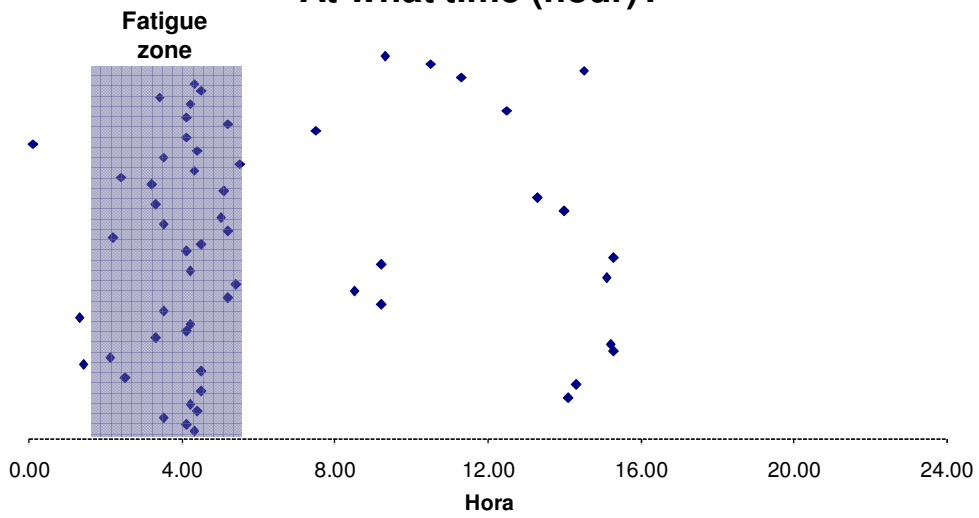
When the accidents occur?



5-years sleep & fatigue work-related accidents analysis (2007-2011)
n = 57
Workers = 5300

D _ N _ D _ N _ _ _

At what time (hour)?



Methods

The methodology is based on the paired comparison model developed by Dean & Nishry (1965)*, which is used to compare alternatives.

Twenty-three (23) variables related to operational, psychosocial and shift pattern design factors were identified and evaluated in a paired approach by 16 experts representing different disciplines.

*** Dean B. and Nishry M. (1965). Scoring and profitability models for evaluating and selecting enginnering projects. Operations Research. Vol. 13 – No. 4 (Jul-Aug) pp. 550-569**

1. Selection of categories and variables

Operational category		Psychosocial category		Shift design category	
1	Working conditions	10	Acceptance by workers	16	Continuous days per shift
2	Breaks during working day	11	Commuting time	17	Days off
3	Productivity	12	Extra-labor activities	18	Time starting the shift
4	Cost of lunch	13	Time with family	19	Time to finishing the shift
5	Accidents	14	Salary	20	Working during the night
6	Manpower	15	Security	21	No. of hours per day
7	Cost of transportation				
8	Time beginning the shift				
9	Absenteeism				

The categories (operational, psychosocial and shift design) were chosen by a panel of experts (Delphi method).

2. Hierarchy of categories

Category	Operational variables	Psychosocial variables	Shift design variables	Sum	Total percent
Operational variables		7	5	12	40
Psychosocial variables	3		5	8	27
Shift design variables	5	5		10	33
Total	8	12	10	30	100

Each category is compared with other categories (or variables) giving a numeric values, 0 = not important, 10 = very important.

3. Hierarchy of variables (Psychosocial example)

Category	Acceptance by workers	Commuting time	Extra-labor activities	Time with family	Salary	Security	Sum	%
Acceptance by workers		7	6	6	7	3	29	19.3
Commuting time	3		5	6	4	7	25	16.7
Extra-labor activities	4	5		5	5	8	27	18
Time with family	4	4	5		4	7	24	16
Salary	3	6	5	6		8	28	18,7
Security	7	3	2	3	2		17	11.3
Total	21	25	23	26	22	33	150	100

Each category is compared with other categories (or variables) giving a numeric values, 0 = not important, 10 = very important.

4. Selection of shift to compare

Shift schedule options	
DN_DN_ _ _	First night 6h
DN(10h) _ DN(10h) _ _ _	
DN_DN _ _ _	Lodging during nights
DDNN_ _ _ _ DDNN _ _ _ _	Lodging second and third day of shift
DDDD_ _ _ _ NNNN _ _ _ _	Lodging every day
2D1N_1N_1N_3D_ _	10h per shift
DN_DN _ _ _	Current shift
DN_DN _ _ _	Beginning 08:00; Finishing 20:00
7D _ _ _ 7N _ _ _ _	Company XXX
8-hour shift	

References to shift schedule	Escondida	Chile
	Piedra Blanca	Chile
	El abra	Chile
	Collahuasi	Chile
	Barrick	Chile
	Cerromatoso	Colombia
	Drummond	Colombia
	FreePort Safford AZ	USA
	Bronce	Chile
	Chuquicamata	Chile

5. Hierarchy of shift schedules to comparison (commuting time example)

Commuting time	DN_DN_ _ _ (First nigh 6h)	DN(10h) _ DN(10h) _ _ _	DN_DN_ _ _ (Lodging during night shift)	DDNN _ _ _ _ DDNN _ _ _ _ (Lodging every day)	2D1N_1N_1N _3D (10h per day/night)	…	Sum	%
DN_DN_ _ _ (First nigh 6h)		7	6	6	7	3		
DN(10h)_ DN(10h) _ _ _	3		5	6	4	7		
DN_DN_ _ _ (Lodging during night shift)	4	5		5	5	8		
DDNN _ _ _ _ DDNN _ _ _ _ (Lodging every day)	4	4	5		4	7		
2D1N_1N_1N _3D (10h per day/night)	3	6	5	6		8		
…	7	3	2	3	2			
Total								

1. Combining all variables

Best

1	DN _ DN_ _ _ (First night 6h)
2	**Current shift DN_DN _ _ _**
3	DDNN_ _ _ _ DDNN_ _ _ _ Lodging (second and third day of shift)
4	DDDD _ _ _ _ NNNN _ _ _ _ (Lodging every day)
5	DN(10h) _ DN(10h) _ _ _
6	DN_DN _ _ _ (Beginning at 08:00)
7	2D 1N _ 1N_1N_3D _ _ (10h per day/night)
8	7D_ _ _ 7N _ _ _ _ Company XXX
9	8-hours shift

2. Only fatigue variables

Best

1	(6.30)	7D / 7 off (12h)
2	(5.34)	DN _ DN_ _ _ (First night 6h)
3	(3.12)	DN(10h) _ DN(10h) _ _ _
4	(3.06)	D 1N _ 1N_1N_3D _ _ (10h per day/night)
5	(2.60)	DN_DN _ _ _ (Beginning at 08:00)
6	**(2.52)**	**Current shift DN_DN _ _ _ (05:30 – 17:30)**
7	(2.52)	DN_DN _ _ _ (06:00 – 18:00)
8	(2.47)	DDNN _ _ _ _ (06:30 – 18:30)
9	(2.27)	DN_DN _ _ _ (08:00 – 20:00)
10	(1.13)	DDNN_ _ _ _ DDNN_ _ _ _
11	(0.95)	NN_DD _ _ _ (12h)
12	(-1.70)	8-hours shift
13	**(-1.89)**	**7D – 7off – 7N – 7 off**
14	(-1.97)	7D_ _ _ 7N _ _ _ _ Company XXX

Discussion – Conclusions

- There is not perfect shift-schedule.
- The best shift schedule should include the acceptance by workers, Union, and administration.
- Using a mathematical model (Dean & Nishry (1965), it is possible to compare the current shift-schedule with others.
- The mathematical model made more objectively the subjective variables commonly involved during the design of shift schedules.
- People expertise give an additional benefit to the model (Delphi method).