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## INTRODUCTION

Health and safety managers face complex challenges in today's production environments. They are confronted with increasingly flexible, autonomous and polyvalent contexts. Asymmetry of information on the workplace is widespread because various intervening parties rely on information lacking conformity. Social partners generate and use information which supports or benefits their pursuit of differing goals. Ascertaining and controlling this information can prove both difficult and costly. When addressing health and safety issues, one intervening partner alters or changes behavior in response to changes introduced by the other side.[1] Strategic behaviors result, based on post-contract opportunism (moral hazard) and alliances with partners who can reasonably be expected to deliver predictable and effective contributions toward individual goals (adverse selection). These behaviors arise out of diagnostic problems, difficulty in determining acceptable risk, asymmetries in the information used in risk taking decisions on the part of social partners and the operation of health and safety systems.[2]

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1. Marcel Simard & Alain Marchand. *Workgroups' Propensity to Comply With Safety Rules: The Influence of Micro-Macro Organisational Factors*, 40 Ergonomics 172, 185 (1997).

2. Bernard Fortin & Paul Lanoie, *Effects of Workers' Compensation: A Survey*, < http://www.cirano.qc.ca/pdf/publication/98s-04.pdf > 1-2 (accessed June 23, 2003).

Many studies show that intervening parties in health and safety are not economically passive.[3] The health and safety system can become a work substitute.[4] Other studies have found a correlation between reduced generosity attributable to unemployment insurance and increases in the mean time of absenteeism compensated by the Health and Safety Commission of Quebec (C.S.S.T.: Commission de la santé et de la sécurité au travail du Québec).[5] These studies also found an association between reduced unemployment allowances and a higher incidence of cases based on selective revelations or voluntary and planned manipulation of information.[6] Other studies have found that injuries posing more difficult diagnosis than bruises and lacerations, for example, are most often reported on the first day following a holiday.[7] Finally, some studies showed that the health and safety compensation system of the Health and Safety Commission of Quebec has had an effect on the nature of injuries reported. Increases in the anticipated compensation generate higher incidence in non-related work injuries and injuries difficult to diagnose.[8]

Many experts and managers have favored incentives promoting active worker participation to thwart such strategic behaviors, but these are difficult to design.[9] Others have developed a risk management approach called participating ergonomics, where the intervention process is advisory, rep-

3. James R. Chelius, *The Influence of Workers' Compensation on Safety Incentives,* 35 *Indus.& Lab. Rel. Rev.* 235, 236 (1982); John D. Worrall & David Appel, *The Impact of Workers' Compensation Benefits on Low-back Claims,* in *Clinical Concepts in Regl. Musculoskeletal Illness* 8 (Norton M. Hadler ed., Grune and Stratton 1987); Alan B. Krueger, *Incentive Effects of Workers' Compen. Ins.,* 41 J. Public Econ. 73, 74 (1990); Marian C. Moore & W. Kip Viscusi, *Compen. Mechanisms for Job Risks: Wages, Workers' Compensation, and Product Liability* 228 (Princeton U. Press 1990); Richard J. Butler, *Lost Injury Days: Moral Hazard Differences Between Tort and Workers' Compensation,* 63 J. Risk & Ins. 405, 409 (1996); Harold H. Gardner et al., *Disability Benefits When Workers Matter,* 2 Mind/Body Med. 138, 146 (1996); Denis Bolduc et al., *Incentive Effects of Public Insurance Programs on the Occurrence and the Composition of Workplace Injuries,* < http://www.cirano.qc.ca/pdf/ publication/ 97s-24.pdf > 1 (accessed June 23, 2003); Fortin, *supra* n. 2, at 1-2.

4. Garder, *supra* n. 3, at 146; Harold H. Gardner & Richard J. Butler, *A Human Capital Perspective for Cumulative Trauma Disorders: Moral Hazard Effects in Disability Compensation Programs,* in *Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work* 231-250 (S. D. Moon & S.L. Sauter eds., Taylor & Francis 1996).

5. Bernard Fortin et al., *Is Workers' Compensation Disguised Unemployment Insurance?* <http://www.cirano.qc.ca/pdf/publication/97s-24.pdf> 2 (accessed Apr. 10, 2003); Fortin, *supra*, n. 2, at 1-2.

6. Fortin, *supra* n. 5, at 1-2; Fortin, *supra* n. 2, at 1-2.

7. Robert S. Smith, *Mostly on Monday: Is Workers' Compensation Covering Off-theJob Injuries?,* in *Benefits, Costs, and Cycles in Workers' Compensation* 115-27 (Philip S. Borba & David Appel eds., Kluwer Academic Publishers 1990).

8. Fortin, *supra* n. 2, at 1-2; Bouldic, *supra* n. 3, at 1-2.

9. Mario Roy et. al., *Équipes Semi-Autonomes de Travail. Recension D'écrits et Inventaire D'expériences Québécoises* IRSST, report B-052, 45 Canada (1998).

resentative of all the social partners and directed toward a consensus.[10] Drawbacks to this approach include vulnerability to group dynamics and conflict over dominance. Training and awareness efforts have been used as didactic material[11] without a clear reduction in injuries such as low back pain.[12] As Goguelin states "[t]o make risk known is in general a good thing, but insufficient. We must try to understand why the consciousness of the risk is insufficient and evaluate how one can go further."[13] Government interference through legislation has also been used to restrict injury coverage. Each of these initiatives aims to encourage the cooperation needed among managers and workers and has proved successful in this sense in a number of organizations.

Inevitably, effective and efficient management of health and safety must spring from an understanding of the dynamics governing the intervening parties. This paper makes use of non-cooperative game theory to identify conditions fostering cooperation between managers and workers as social partners in the workplace.

## METHODOLOGY: GAME THEORY

Non-cooperative game theory models situations in which individuals make decisions unilaterally without consulting other intervening parties. According to Riggs et al., the subject of game theory is situations where "a competitive environment presupposes intelligent opponents capable of exerting influence over our outcomes through their choice of action, while

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10. Patrick Loisel et al., *La clinique des maux de dos. Un modèle de prise en charge, en prévention de la chronicité*, IRSST, report R-140, 37 Canada (1996); Louis Patry et. al., *Participatory Ergonomics and Prevention of Low Back Pain*, William S. Marras et al., *The Ergonomics of Manual Work*, 523-526 (William S. Marras et al. eds., Taylor & Francis 1993); Ilkka Kuorinka et al., *Participation in Workplace Design With Reference to Low Back Pain: A Case for the Improvement of the Police Patrol Car,* 37 Ergonomics 1131, 1133 (1994); Veronique De Keyser, *La démarche participative en sécurité,* 33 Bulletin de Psychologie 479, 489 (1980).

11. Ken L. Donajkowski, *Back Injury: Causes, Prevention, Treatment Prof. Safety*, September, 21-26 (1993).

12. John D. Benson, *Control of Low Back Pain: Using Ergonomic Task Redesign Techniques,* 32 Prof. Safety 21, 22 (1987); Steven A. Lavender & Ron Kenyeri, *Lifting Belts: A Psychophysical Analysis,* 38 Ergonomics 1723, 1723 (1995); Stover Snook et al., *The Design of Manual Handling Tasks,* 21 Ergonomics 963, 1197 (1978); Peter Mandell et al., *Low Back Pain* 219 (Slack Inc. 1989); Ilkka Kuorinka et al., *Manual Handling in Warehouses: The Illusion of Correct Working Postures,* 37 Ergonomics 655, 660 (1994); Monique Lortie et al., *Analyse des Accidents Associés au Travail de Mmanutentionnaires sur les Quais dans le Secteur Transport*, 59 Le Travail Humain 180, 187 (1996).

13. Pierre Goguelin, *Risque et Prise de Risque: Les Concepts*, in *La Prise de Risques dans le Travail* 29 ( Pierre Goguelin & Xavier Cuny eds. 2001).

concurrently we choose a course of action that maximizes our returns with respect to the opponents' anticipated activities."[14]

Much of the conceptual framework draws on work by mathematicians Von Newman and Nash in the 1940`s and early 1950`s. On one hand, this model demonstrates that effective individual strategies or behaviors do not necessarily create a situation that is best for all. On the other hand, given certain conditions, it confirms that cooperation can exist without formal agreement among the intervening parties.

Game theory has been used to understand and organize both human and animal activity. As a decision theory, it helps to explain possible strategic behaviors of individuals without defining the final tactics. Many textbooks cover the topic and its application in varying fields.[15]

## MODEL: SIMULTANEOUS GAME WITH PERFECT AND INCOMPLETE INFORMATION

Workers and management seek to achieve their respective goals by choosing preferred actions based on inferences about steps that will be taken by the other party. Expectations concerning such actions are based on these hypotheses:

- Each player (decision-maker) possesses information on the rules and conditions of the game (social situation);
- Players are rational ("he makes decisions consistently in pursuit of his own objectives");[16]
- Players seek to maximize the anticipated value of their own payoffs, that can be described by an utility function;
- Players are intelligent (he "knows everything that we know about the game and he can make any inferences about the situation").[17]

Since Milgrom and Roberts[18] have shown that theories based on perfect rationality and adaptability are successful in generating predictions about

14. James L. Riggs et al., *Engineering Economics* 564 (McGraw Hill 1986).

15. *See* Jean Tirole, *The Theory of Industrial Organization* (MIT Press 1988); Drew Fudenberg & Jean Tirole, *Noncooperative Game Theory for Industrial Organization: An Introduction and Overview Handbook of Industrial Organization* vol. 1 (Elsevier Science Publishers 1989); David Kreps, *Game Theory and Economic Modelling* (Clarendon Press England 1990); Avinash K. Dixit & Barry J. Nalebuff, *Thinking Strategically: The Competitive Edge in Business, Politics, and Everyday Life* (W.W. Norton & Co. 1991); Roger B. Myerson, *Game Theory Analysis of Conflict* 1-7 (Harvard U. Press 1991).

16. Myerson, *supra* n. 15, at 1-7.

17. Myerson, *supra* n. 15, at 1-7.

organizations and their practices, the rationality hypothesis is appropriate, even essential, to the analysis of technical situations.

However, the assumption that all individuals are perfectly rational and intelligent may never be satisfied in any real-life situations as claimed by Myerson.[19] Conversely, a prevention program based on irrational behaviors will lead most likely to an ineffective situation.

In this problem, management's and workers' motivations as well as the variables modulating their choice of actions are well known. Management allocates resources in health and safety owing to legal obligation, as the result of an economic decision or awareness of problems.[20] Workers will engage in health and safety consistent with their personal objectives and their perception of the risks present in their environment.[21] Not to be overlooked, however, are asymmetries of information concerning the health of workers and the risk taking decisions made by social partners. The model must also deal with diagnostic uncertainties, the difficulty in assessing risks present in the workplace and determining what level of risk is tolerable. Workers and managers cannot know with preciseness and certainty the value each other has assigned to the different variables modulating their choice of actions, nor the commitment the other makes to health and safety. In game theory, this type of interaction can be modeled by games with incomplete and imperfect information.[22] In this paper, we use a game with perfect information (the players know the history of the decisions taken in the past). It is a reasonable hypothesis so long as the tactical factors are not broached. Pervasive asymmetries surrounding information relative to the effort directed at health and safety justify use of a simultaneous, rather than a Bayesian, game.

18. Paul Milgrom & John Roberts, *Economics, Organization and Management* Ch. 1-7 (Prentice Hall 1997).

19. Myerson, *supra* n. 15, at 1-7.

20. Sylvie Nadeau, *Outil d'analyse Multifactorielle Pour la Prévention des Maux de Dos* 116, 118, 147 (unpublished Ph.D thesis, École Polytechnique de Montréal, Département de Mathématiques et de Génie Industriel 2001) (on file at Natl. Lib. Canada).

21. *Id*.

22. Myerson, *supra* n. 15, at 1-7 ("at the first point in time when the players can begin to plan their moves in the game, some players already have private information about the game that other players do not know").

In this paper, we use the strategic (or normal) form to represent the game. Therefore,

$\Gamma = (N, (Ci)i \in N, (ui)i \in N)$

where

*N* is the set of players in the game
*i* is the player
*Ci* is the set of strategies available to player *i*
*ui* is the expected utility payoff that player *i* would get in this game

A strategy profile (C) is a combination of strategies that the players might choose

$$C = X_{i \in N}\, Ci$$

In our problem,

$N = \{1, 2\} = \{$workers, managers$\}$
$C^1 = C^2 = \{$*improve* efforts in health and safety, *maintain* efforts in health and safety as is$\}$

Four outcomes are possible:

$C = \{(a_1$=improve, $a_2$=improve), (improve, maintain), (maintain, maintain), (maintain, improve)$\}$

Efforts in health and safety can be considered laborious, costly and not necessarily maximizing the individual utility payoff. There may be situations in which any small private effort in improving health and safety yields immediate and tremendous returns. But the optimization of efficiency of health and safety measures depends on the synergy of actions taken by the social partners. Consequently:

- If workers and managers both improve their efforts in health and safety, their expected individual utility payoff will incur lower cost.
- If both maintain their efforts in health and safety, expected individual utility payoff will prove costly.
- If one partner improves its efforts in health and safety, which is a very costly individual decision, the other will benefit from these efforts. More precisely, if a health and safety program goes off-course, or if workers claim it is ineffective, workers may benefit

from these efforts but they are very costly to management. If workers' efforts go unrecognized or are not sustained by the firm, however, the individual payoff is costly to workers while managers benefit (through lower their insurance costs, for example). The following utilities emerge:

$u^1$ (improve, improve) = $u^2$ (improve, improve) = less costly situation
$u^1$ (improve, maintain) = $u^2$ (maintain, improve) = very costly situation
$u^1$ (maintain, improve) = $u^2$ (improve, maintain) = beneficial situation
$u^1$ (maintain, maintain) = $u^2$ (maintain, maintain) = costly situation

This game may be represented in a tabular form, as represented in Table 1:

Table 1
Game in Tabular Form

| | | MANAGERS | |
|---|---|---|---|
| | | Improve | Maintain |
| WORKERS | Improve | (less costly, less costly) | (very costly, benefic.) |
| | Maintain | (benefic., very costly) | (costly, costly) |

## DISCUSSION: EQUILIBRIUM OF THE GAME

We need to determine where the game leads the partners in terms of the possible outcomes. In this game, we can identify a Nash equilibrium (a combination of strategies that neither player will regret after assessing the choices made by other players), precisely:

$$u^i(c^{*i}, c^{*-i}) \geq u^i (c^i, c^{-*i}), \forall c^i \in C^i$$

This strategy seeks to maintain without change efforts in health and safety. We can also identify a Pareto efficiency equilibrium (the outcome of a game is Pareto efficient if the outcome of a player cannot be improved without diminishing the outcome of others):

the result $c^\wedge$ dominates the result c if:

$$u^i (c^\wedge) \geq u^i (c), \forall i \text{ and}$$

$$\exists\, j, u^j (c^\wedge) > u^j (c)$$

In our game, (improve, improve) is a Pareto efficiency equilibrium.

The health and safety game is similar to the Prisoners' Dilemma.[23] The equilibriums found provide a clear indication of how the intervening parties will interact in the real world. In this game, rationally, the social partners ought to maintain the status quo in terms of efforts in health and safety (Nash equilibrium). They ought to avoid the moderate decision, in terms of expected individual payoff, which is to improve efforts in health and safety (Pareto efficiency equilibrium). Therefore, the rational individual strategies will lead to an outcome that is bad for all social partners. In this type of problem, we can command effective and efficient co-operation between workers and managers so long as the time span of the game is unknown. This has been demonstrated using genetic algorithms by Axelrod[24] and others.[25]

Analysis of interactions among workers and managers in health and safety, using game theory, brings us to conclude that if cooperation can be established, it has good chances for survival. There are two important factors in establishing such cooperation:

1. Acting on the costs and benefits of initiatives in health and safety. Wilde,[26] in his homeostasis theory, points us in this direction:

- One should reduce the benefits of taking health and safety risks, which may be done by the use of appropriate legislation or intra-firm politics;
- One should reduce the cost of making efforts to improve health and safety, which may be done by modifying the insurance fees or by promoting the use of safety groups;
- One should increase the benefits making efforts to improve health and safety, which is the object of different incentive measures and may be done by the use of appropriate training programs and certifications;
- One should increase the cost of taking risks in health and safety, which is currently done by legislation.

23. R. Duncan Luce & Howard Raiffa, *Games and Decisions* Ch. 5 (Wiley 1957).
24. Robert Axelrod, *The Evolution of Cooperation* Ch. 7 (Basic Books 1984).
25. Fudenberg, *supra* n. 15.
26. Gerald J. S. Wilde, *Beyond the Concept of Risk Homeostasis: Suggestions for Research and Application Towards the Prevention of Accidents and Lifestyle-Related Disease,* 18 Accident Analysis and Prevention 377, 401 (1986).

2. Changing the rules and conditions of interactions by establishing implicit and explicit contracts in health and safety prevention. In previous results,[27] we have proposed an ergonomics intervention approach leading to the establishment of common and objective information on the health and safety risk factors. Making explicit contracts and accepting this information binds the social partners and limits the strategic behaviors, increasing the probability of success of the intervention in health and safety. This implicit contract is one of the conditions under which co-operation will take place without any legal intervention in either the infinite or the indefinite versions of the game.

Our analysis indicates that a range of measures may be employed to encourage and facilitate co-operation which might not occur in their absence.

## CONCLUSION

In this paper, we have demonstrated that incompatibility exists in the aims and strategies of the social partners with respect to health and safety. This situation can prove inefficient or unproductive for all. Management of health and safety needs to consider the strategic behaviors practiced by intervening parties to introduce measures that are effective as well as efficient. Both implicit and explicit contracts must be constructed to address dominant behavior and to facilitate co-operation on health and safety issues.

27. Nadeau, *supra* n. 20, at 116, 118, 147.