MODELING THE INTEGRATION OF OCCUPATIONAL HEALTH AND SAFETY RISKS WITH OPERATIONAL RISKS ASSOCIATED WITH AUTONOMOUS AND MULTI-SKILLED WORK PERFORMED IN UNCERTAIN ENVIRONMENTS

Sylvie Nadeau[1], Jean-Pierre Kenné[1] and Paul Alexandru.[1]

[1]Département de génie mécanique, École de technologie supérieure, Montréal (Québec) H3C 1K3, Canada
sylvie.nadeau@etsmtl.ca

ABSTRACT

Sharing information poses a significant challenge in attempting to integrate and manage occupational health and safety in response to operational risks where autonomous and multi-skilled work is performed in uncertain environments. Managers and workers stand to benefit from a model developed as a prototype for an information system that is based on data flow technique, skills characteristic of autonomous and multi-skilled workers, and which rests on systemic analysis of the technological sub-system prevalent within a firm. Our knowledge of econometrics leads us to endorse training and exchanges aimed at promoting awareness of risks and upgrading job know-how among workers. Once the regulated risks and the risks unanimously recognized by health and safety experts have been controlled, we offer here a guide in reaching a preliminary decision that integrates parameters commonly associated with commercial efficiency and diligence in the pursuit of workplace health and safety. Lastly, findings have been validated through a case study carried out among firms engaged in the moving industry.

RÉSUMÉ

L'intégration de la santé et de la sécurité du travail aux risques opérationnels dans le travail autonome et polyvalent en environnements incertains comporte un défi important en ce qui concerne le partage de l'information sur les risques et la gestion de ces risques en incertitude. Pour soutenir les gestionnaires et les travailleurs, un modèle prototype de système d'information a été conçu à partir de la technique des flux de données, les connaissances caractérisant les travailleurs autonomes et polyvalents en environnements incertains, les comportements stratégiques des acteurs principaux et repose sur l'analyse systémique du sous-système technologique d'une entreprise. Ensuite, à partir de connaissances en économétrie, il a été recommandé de favoriser la formation et l'échange sur les risques et les savoirs de métiers des travailleurs. Une aide à la décision préliminaire, intégrant les paramètres prépondérants d'efficacité commerciale et de diligence en santé et en sécurité du travail, a été proposée. Finalement, une validation par l'étude du cas de l'industrie des transporteurs neufs et usagés a été faite.

1 INTRODUCTION

Profound changes have occurred within organizations owing to technological advances, the advent of global markets and deregulation in all its forms: Systems of production have grown more integrated and dynamic. Accordingly, we need to make full use of our technical advances and know-how to make products high in value added content (1), customer oriented and in high volumes. New modes of managing activities are thus envisaged, firms constantly striving for greater flexibility and productivity (2). Autonomous and multi-skilled work is now embraced widely (3,4) though it has existed formally for thirty or forty years in the automotive industry (5,6,7,8). In uncertain work environments, however, management of preventive activities in occupational health and safety has gone largely unacknowledged, forgotten or ignored. This can lead to real losses in efficiency when inadequate preventive measures leave workers exposed to serious risks. The pathway to a solution now favoured by a number of researchers is a global approach to risk management within a firm that integrates occupational health and safety with operational risks.

Autonomous and multi-skilled work in uncertain environments poses two significant challenges in this regard:

- Several players need to share information concerning risks and coordinate their activities, all the while maintaining self-management among workers performing greatly enriched tasks;
- Activities themselves contribute to a significant level of uncertainty owing to a work environment noted for change and unexpected developments.

In this context, we observed an increase in situations where information asymmetries can prove deciding factors (9, 10). Traditional channels of communication (employers, occupational health and safety committees, prevention officials) and courts are poorly equipped to share information on risks (9,11).

Modeling integrates a number of functions and conforms to needs and vital concerns confronting business systems that are increasingly complex and dynamic (12, 13, 14). The appearance of new industrial risks and ethics enhances these needs. In this regard, a number of avenues have been explored recently in an effort to come up with solutions that integrate health and safety with:

- Management and improvement in the organization of work (15, 16);
- Management of continuous improvement, implementing approaches such as Kaïzen (17);
- Management of quality and the environment (18);
- Business systems management (19), using total quality (20) or remuneration models (21);
- Design of manufacturing systems (22, 23, 24);
- Organizational factors and control of major risks (25);
- Planning of manufacturing systems (26, 27, 28);
- Audits of suppliers (29);
- Management of industrial projects (30);
- Training and practice of engineers (31, 32).

Unfortunately, designers and planners of flexible production systems in uncertain environments (whether for goods or services) find it difficult to integrate these recommendations in their systems (13).

The goal of this article is to develop a model to manage occupational health and safety risks that adapts to enterprises where autonomous and multi-skilled work prevails. We are more particularly interested in uncertain environments.

More specifically, we turn our attention to:

- Studying ways to adapt the management of operations, particularly information systems (design and planning of production) shared by those giving orders and those carrying them out, without negative impact on operational efficiency;
- Offering ways to organize work carried out by those engaged in occupational health and safety (designers of processes, managers and workers) that responds to the paradigms of modern production and limits asymmetries in the information shared among all players;
- Validating the model developed through case study of the residential and commercial moving industry.

Integrated management of risks itself is a difficult undertaking; it obliges those involved to identify, analyze, deal with and follow up on the evolution of a set of risks capable of affecting a company, recognizing that such risks are not uniform. Certain risks are measurable while others are misconstrued or difficult to evaluate (33, 34).

The following two recommendations are offered recognizing that all things can never be known in advance, that simply complying with legislative requirements proves inadequate, that due diligence is required, that calculating acceptable risk is difficult, and that strategic behaviours may come into play (selective disclosure, knowing and calculated manipulation of data):

- Do not embark on unilateral initiatives in occupational health and safety, but seek instead to establish a strategic partnership supported by all those engaged in prevention (35, 36);
- Encourage sharing, ownership and objectivity of information dealing with risks (35).

2. Methodology

In this regard, we first conceived a model that might serve as the prototype for an information system that makes it possible to implement occupational health and safety measures in an integrated response to operational risks occurring where autonomous and multi skilled work takes place in uncertain settings. The resulting system relies on our knowledge of data flow technique, skills common among autonomous and multi-skilled workers, uncertain environments, strategic behaviours among principal players (managers and workers) in occupational health and safety, and rests on our systemic analysis of the technological sub-system within a company.

We subsequently applied this model in an industrial case study aimed in part at establishing what attributes an information system requires for effective, efficient and integrated management of operational risks and occupational health and safety, while on the other hand offering a preliminary technological tool in support of decisions (diagnostic and monitoring) made by key players in the integration of parameters consistent with commercial efficiency and due diligence with respect to occupational health and safety.

2.1 Modeling the information system

Systemic modeling lets us understand the dynamic existing among various players directly involved so as to decide which routes to follow in coordinating the desire and effort required for occupational health and safety.

In our earlier work (10, 35), we used game theory to model the conduct of managers and workers in occupational health and safety. We demonstrated that cooperative behaviours can be introduced by taking action on factors having a bearing on costs incurred by managers as well as workers and by altering the rules and conditions under which these partners interact.

This article offers the prototype for a management model that clarifies what information needs to be shared among those involved in prevention at each stage in the design of a product or service.

Data flow technique was used to develop our prototype model and to facilitate:

- Analysis of inputs, processes and outputs;
- Systemic identification of key elements in the management of activities.

This modeling, subsequently supported through in-depth case studies targeting a representative industrial sector, enabled us to acquire greater understanding of questions surrounding the management of occupational health and safety among self-managed teams of workers, conforming as well with recommendations pertaining to semi-autonomous teams found in Roy *et al.* (1998) (37).

2.2. Field testing

According to the Commission du transport du Québec (the Quebec Transport Commission), some 17 190 trucks are currently engaged in the heavy trucking industry. 770 of them have declared having 50% of their activities linked to the moving industry. There are few statistics for this industry. The associations representing it estimate there is 268 moving companies in Quebec, owning 8 622 trucks and hiring 1 437 employees: a very conservative estimate neglecting the influence of the new entrants and the manpower consultants. It is a deregulated industry where new entrants spring up when the weather gets good, only to disappear with the first snow fall. Moving firms still constitute an interesting field for our study, however, because asymmetries in information contribute to entropy that hampers communication among managers, contractors and customers.

We consulted company documents, witnessed moving activities, conducted semi-directed and one-on-one interviews with workers and managers of firms using grids of observations and interview questionnaires developed and used in an earlier study (35) and approved by the committee on human ethics and research at l`École de technologie supérieure.

This work serves to inform our current efforts with respect to:

- The strategic system by which a firm delineates policies related to the management of operations, policies related to occupational health and safety as well as policies related to quality;
- The system followed by a firm with respect to its preventative program, the roles and responsibilities assigned to managers, workers, the CSST inspector, production planning, incentives and contracts governing the performance of work;
- Supply and technological systems a firm uses in its operations, equipment, adaptations and the environment, parameters surrounding work and work activity.

Four (4) moving companies participated in the study, varying in size, organizational format (parent company or subcontractor), type of goods transported, area served and equipment used. We therefore

obtained a representative sample of the type of activity carried out in this service sector:

- Company 1: This firm has seven (7) full time employees, four (4) to ten (10) temporary workers. Residential moves account for 70% of business, commercial, 30%. Firm has existed 10 years. No workplace accidents declared for 10 years, though managers and workers cited incidents considered minor.
- Company 2: This firm employs sixty (60) workers and many others on contract. It specializes in deliveries of furniture and household appliances for a prime manufacturer. Some 60% of workers said they experienced back problems at least once during the year. And 70% of accidents occur while moving appliances.
- Company 3: This firm specializes in long distance moves. Thirty-five (35) employees work here on teams supported by a number of other workers on contract. No accidents were reported in the 243 days preceding our study.
- Company 4: This firm offers service throughout eastern Canada, has several warehouses and engages in commercial and residential moves as well as the distribution of furniture. The company has a team of some ninety-five (95) permanent employees and about forty (40) workers on call. Receiving and forwarding merchandise, labelling goods and their movement are all controlled and followed through bar codes. The company offers national and international transportation by land, water or air. The nature of its activities lends itself to overnight shipments. The company refused to supply statistics relating to accidents.

Fifty-six (56) workers participated in the study out of 321 available at companies taking part in our study. Companies surveyed average 56 moves a month. We watched 22 moves in 6 months and conducted 76 semi-directed interviews with workers and managers.

2.3. Preliminary technological tool for the integration of predictors for commercial efficiency with those for diligence in occupational health and safety: Analytical modeling of the level of service

Level of service is a prime measure of performance in the moving industry. Requests for handling and transport must be carried out without damaging whatever is to be moved, in a truck with limited capacity, where loading and destination points are fixed, the work environment changes, where efficient interaction is required with one or more clients, to meet deadlines at a cost of service severely constrained by the competition.

In their work, Stancioiu and Militaru (1998) (38) maintained that the level of service could be modeled analytically as expressed in the following equation:

$$H_i = a\sum_{j\in S_1}\gamma_j\frac{x_{ij}}{x_{kj}} + \sum_{j\in S_2}\gamma_j\frac{x_{kj}}{x_{ij}} \qquad (4.1)$$

where

H_i : represents the level of service possible given the resources allocated i ;

x_{ij} : is a risk factor acting on the quality of output for the task j, given the resources allocated for the service i;

x_{kj} : is the value of this risk factor for an operation k of task j;

γ_j : is the importance of task j in the definition of the level of service;

a : a constant;

i : service;
j :task;
k : operation;
S1: subset of risk factors directly affecting the level of service H_i and in line with the quality of output for a set of tasks;
S2: subset of risk factors having values directly proportional to the level of service H_i and consistent with the quality of a set of operations.

3. Results

3.1 Implementing an appropriate information system

Self-managed and multi-skilled workers assume various responsibilities, managing their work, setting their own rules and must display initiative and creativity in the completion of their tasks (37). To do so, they need to know the formal content of work expected (variables pertinent to its completion, criteria used in performance assessment, occupational risks) for each of the tasks to be performed, to adopt work methods and choose equipment meeting realities of the job at hand. So, to the extent that we want workers and managers to manage the way in which risks are integrated when a client calls for service, we need an information system (see figure 1) that draws together details related to the formal content expected from an operational viewpoint as well as that for occupational health and safety. It is therefore necessary to produce a multi-dimensional and multi-level assessment of these risks.
In uncertain environments, as in other settings, workers need to assess the risks present. In their activities, workers must make an incalculable number of decisions concerning such risks. Taking into account the large number of factors to consider, complexity involved in assessing the latter and their contribution to the global risk involved in their assignments, workers are apt to focus their attention on certain risk factors only. In uncertain settings, moreover, some risks are unknown or unexpected. Workers need to react at the moment when planning occurs concerning how jobs will be performed and not when they are performing the work itself. To do so, we need to construct here an analytical model (see figure 1) capable of integrating operational risks with those related to occupational health and safety so that an informed decision can be made concerning the risk factors to be addressed and controlled.

3.2 Using the residential and commercial moving industry to validate our results

Movers are especially prone to muscular-skeletal injuries. On the job risks go hand in hand with the uncertain work environment, the physical loads exerted and organization of the work itself.
Principal activities involved in moving are:

- Packing bedding, books, clothes along with various fragile objects;
- Packing clothes on hangers in wardrobes;
- Packing and unpacking dishes, glassware and other fragile objects;
- Safeguarding picture frames, paintings and mirrors;
- Dissembling and reassembling furniture;
- Protecting furniture with covers;
- Placing furniture as directed by customers.

Lifespan of a truck varies with the type of moving done, mileage accumulated, and types of loads

carried. A company`s image depends, among other things, on the use and general upkeep of its trucks. In a number of firms, a truck stays in operation 7 to 8 years. Workers attach a great deal of importance to the comfort level afforded by the truck with respect to sources of vibration and noise. Moves are performed using manual handling equipment such as: belts, dollies, carts and chain hoists. Tools are needed to dissemble and reassemble furniture.

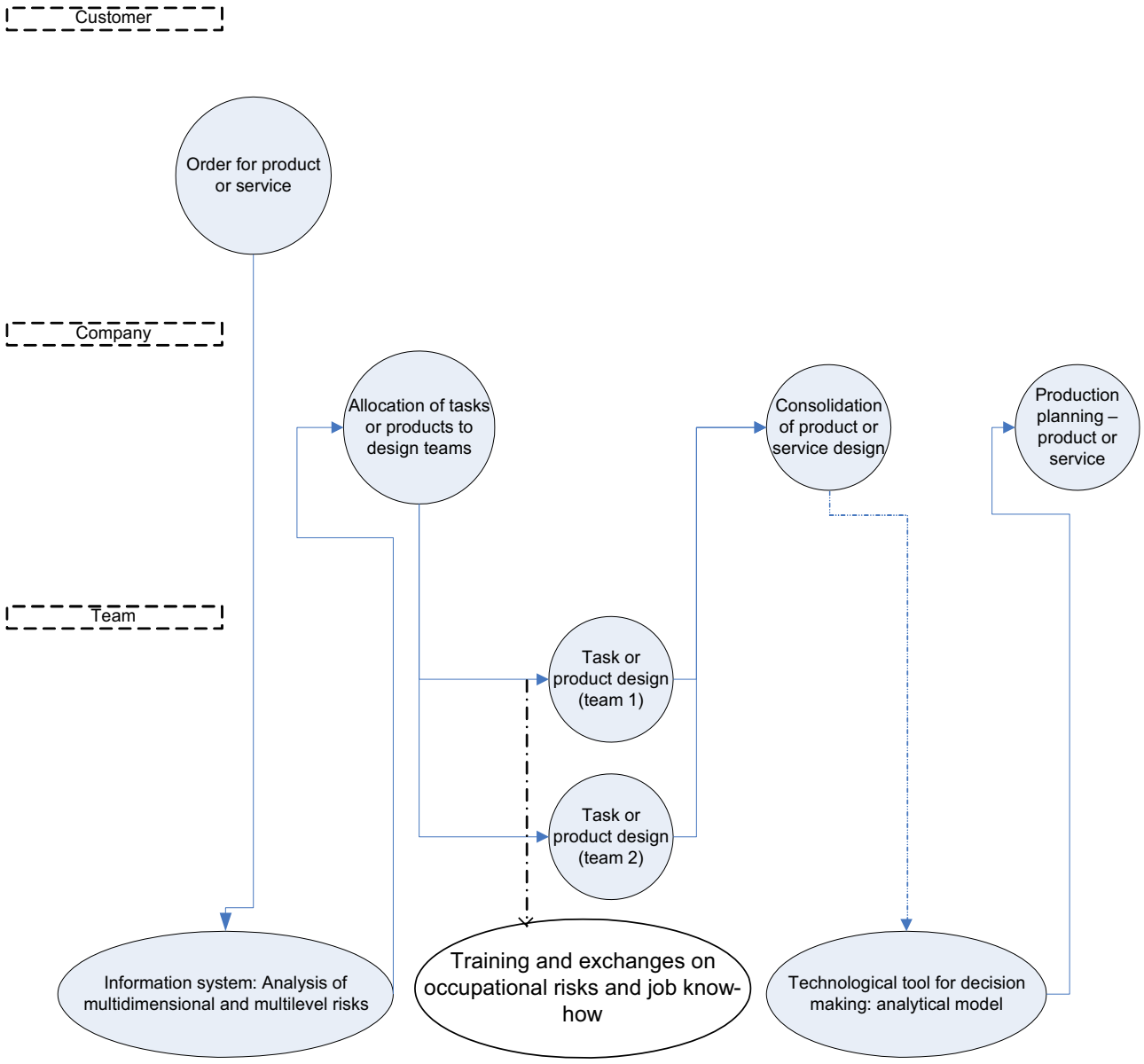

Figure 1: Prototype model for the integrated management of autonomous and multi-skilled work performed in uncertain environments validated in a case study of furniture movers

Safety shoes and protective gloves are worn as personal protective equipment. In many companies, no standard governs this equipment and no budget exists to support workers in their purchase, suggesting why certain equipment is always in a state of disrepair. In exceptional cases, however, certain commercial movers oblige workers to wear hard hats and protective glasses. Reflective clothing is required for moves occurring at night.

Method and quality of work depends on a number of variables. The manager (team leader or experienced mover) is responsible for defining methods of work based on his observations pertaining to the site of the move (rural or urban, residential or commercial, long distance or local), the capability of his team and each of his workers, the scheduling of all moves for the day as spelled out by the company planner, the distance between sites for two moves. In a team composed of two (2) or three (3) workers, autonomy is of the utmost importance. Handling activity needs to be organized. The order in which a truck is loaded and unloaded takes planning. Movers interact as members of a team to coordinate their efforts, to communicate with one another (sometimes in conditions of little or no visibility), where dispatch, tasks assigned or allotted and information shared, proves critical. Handling methods are dictated by:

- Difficulty of the task owing to
    - Architecture at site of the move:
        - Stairs (number and steps, architecture and condition);
        - Narrow spaces (goods may be moved using balconies, windows, emergency stairs, elevators, etc.);
        - Varying coefficients of friction between shoes and ground;
    - Numbers of rooms;
    - Dimensions, weight, special packing and handling of loads (risks increase in the case of refrigerators, cabinets, curios, marble tables, freezers, sofa beds, pianos and other heavy and cumbersome objects);
    - Design, positioning and coefficient of friction for the access ramp to the truck;
    - Design of the loading infrastructure;
    - Haul distance;
    - Weather conditions (sun, rain, snow, heat, cold, humidity) and time of day (day or night);
- Experience of the worker (determined by basic training acquired, the company training program, length of time considered a trainee, seniority and aptitudes);
- Worker's level of fatigue.

A worker's physical ability and skills must determine the nature or content of tasks assigned. Managers are in a position to plan and control physical workloads by rotating tasks, scheduling breaks, days off, introducing new ways to get the work done. There are 35 hours in a standard workweek. Actual workweeks are between 40 and 50 hours, however, reaching 60 hours/week in peak periods. Workers may be more or less consulted concerning tasks assigned and the pace of work depending on the management style of the team leader. Any such consultation usually occurs in a hierarchical manner, those with the most experience often getting the first word.

Movers interact constantly with their customers and this results in its own set of problems: Incomplete addresses, billing and payment problems, loading mistakes, new requirements when work has already started on a move, dissatisfactions, frustrations and stressed customers. It is highly likely traffic will be disrupted at the moving site.

Residential and commercial movers operate in a deregulated environment marked by a shortage of specialized and experienced manpower. Certain firms undertake their own training. Workers are instructed and receive job training in:

- Packing, dismantling, loading and unloading;
- Handling special materials;
- Safety and workplace organization;
- Body positioning when moving a load by hand and with a partner (posture and handling techniques);
- Personal protective equipment;
- Handling and transporting hazardous materials.

Skilled and experienced workers engage in discussions with other movers (see figure 1) to offer training in job know-how and occupational risks.

3.3 Analytical modeling of the level of service: A ground breaking technological tool that integrates requirements for commercial efficiency with those for diligence in occupational health and safety

Risk factors x_{ij} , x_{kj} (operational, occupational health and safety) having a direct bearing on the level of service in the moving industry are as follows:

1) Work methods and techniques;
    a. Inter-task coordination;
    b. Requirements of the task;
    c. Pace of work and sequencing of tasks;
2) Specialized equipment;
    a. uses;
3) Customer relations;
4) Teamwork;
    a. Dispatch, assignment and breakdown of tasks and responsibilities;
    b. Coordination of activities;
    c. Social, cultural characteristics, training and job know-how acquired by workers;
    d. Social and cultural characteristics of the team;
    e. Communications;
    f. Structural characteristics (organization and composition)
5) Physical and mental workload;

Consider S1 the subset for risk factors 3,4,
S2 the subset for 1,2 and 5.
Values γ_j are established to satisfy the conditions:

$$0 \le \gamma_j \le 1 \text{ and } \sum \gamma_j = 1 \qquad (4.2)$$

Matrix integrating risk factors

We have constructed a matrix that integrates risk factors by comparing their relative importance in the following manner:

$$\gamma_j = \frac{\sum_{j_2} a_{j_1 j_2}}{\sum_{j_1}\sum_{j_2} a_{j_1 j_2}}, \qquad (4.3)$$

where $a_{j_1 j_2}$ can assume a number of values:

$a_{j_1 j_2}$ = 1, if the risk factor j_1 of the line in the integration matrix ranks in equal importance with risk factor j_2 in the column of the matrix;

$a_{j_1 j_2}$ = 2, if the risk factor j_1 on the line of the matrix is more important than the risk factor j_2 in the column concerned;

$a_{j_1 j_2}$ = 0, if risk factor j_1 is less important than j_2.

Risk factors are prioritized to determine their relative importance. Assessing and ranking risks in their order of importance can be based on scientific knowledge, political judgments, the values and perceptions of people. We are therefore in a position to advocate a sociological management of risk by generating data and recommendations based on human interactions. We might likewise advocate scientific management of risk, employing methods and tools found in the natural, engineering, and life sciences as well as decision making (39, 40, 41).

The formula for the level of service H_i says that if $X_{ij} = X_{kj}$, then $H_i = H_k = a$, the optimal level in the integrated condition being the constant a.

$$H_i = \begin{cases} H_k, \text{ if } H_i = a \\ > H_k, \text{if } H_i > a \\ < H_k, \text{ if } H_i < a \end{cases}$$

If risk factors x_{ij} and x_{kj} cannot be expressed in continuous functions, or by attributes such as acceptable, very acceptable, good, very good, individual preferences may be introduced to choose a definition of utilities ranging in value from 0 to 1.

4. Discussion and recommendations

Our current study on the residential and commercial moving industry confirms recommendations contained in our earlier work (35) which called on movers to obtain more information on risks when requests for service are received. Companies participating in the study had implemented the system of information proposed through a control list that was more complete concerning critical variables for the sound management of operations, health and safety, a control list used when customers called or visited to place orders. This gathering of information binds those involved in prevention in an implicit contract. But we have now seen the appearance of explicit contracts covering occupational health and safety for workers and subcontractors performing regulated work in Quebec's construction industry.

In our earlier studies (35), we favoured certification in occupational health and safety to qualify for employment or promotion to avoid adverse selection and to recruit those best equipped to contribute effectively to interventions aimed at preventing risks associated with occupational health and safety.

The manager of a move (a team leader or experienced mover) decides what sort of team is required and how work will be carried out (goals, priorities, organization of work, size and composition of the

team, decisions, standards, roles). The transfer of work related know-how among workers is essential for sound organization of occupational health and safety. Members of a moving team must possess the knowledge and skills to carry out their work, but also to be able to communicate and coordinate their activities. The tasks required are demanding and the way work is performed changes constantly. It is not unusual for workers to team up with the same colleagues and on the same equipment. The team attains a certain level of maturity that translates into performance in operational terms as well as occupational health and safety. It is not sufficient to encourage workers to choose their own teams and training where autonomous and multi-skilled work takes place in uncertain environments. It is necessary to foster exchanges among experienced workers and novices dealing with occupational risks and job know-how. The skill and know-how of an employee is an asset. The worker often becomes a partner who is difficult to replace in terms of productivity. A significant community of researchers treats knowledge transfer among workers and the need to acquaint new arrivals with realities in the workplace (42, 43, 44).

The importance attached to risks associated with operations and those arising out of concern over occupational health and safety varies in any given situation and it is therefore always possible to misjudge the probability of their occurrence or the gravity of their consequences – and the influence workers exert on this level of risk is variable. It is recognized that personal interests play an important part in an individual's conduct (45). How, then, to reconcile the interests of the company and those of the worker, all the while acknowledging difficulties associated with the notion of acceptable risk and the goal of improving occupational health and safety? Once the regulated risks and the risks unanimously recognized by health and safety experts have been controlled, we propose, in the first instance, to integrate the risk affecting a resource of prime importance to the company and its workers, namely the level of service, and the risks to occupational health and safety through an analytical model. In other words, we propose to act on factors affecting costs incurred by all those involved (35), enabling managers and workers to operate more prudently by capitalizing on the benefits derived from an external assessment of the firm. Accordingly, our earlier recommendations (35) can now be considered along with those put forward by Wilde (1986) (46).

5. Conclusion

The contribution made by this article is to set out a model that may serve as a prototype to integrate the management of operational risks with those for occupational health and safety. This model includes:

- An information system ensuring the sharing, ownership and objectivity of information on risks;
- A recommendation concerning the training and exchange on risks and job know-how to benefit from the phenomenon of adverse selection and the transfer of experience among workers;
- A preliminary analytical model of the level of service integrating occupational health and safety risks, reconciling the interests of key players (managers and workers) with those of prevention.

Recognizing that research in occupational health and safety is only of interest if it produces concrete measures for prevention, more research is needed to validate the management model proposed through the implementation of pilot projects in other sectors of activity where autonomous and

multi-skilled work is performed mainly in uncertain environments. Our analytical model of the service level needs further work before it can be introduced in the workplace. We must determine what weight to accord various risk factors and reconcile results obtained from quantitative as well as qualitative assessments.

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BIOGRAPHIE

Professor Nadeau plays an active role in the development of the Équipe de recherche en sécurité du travail (ÉREST) (which is made of fourteen members) and the Réseau de recherche en santé et en sécurité du travail du Québec (RRSSTQ) (which is made of 227 members), since 2005. She currently acts as Director for both these entities. She is also codirector of the Laboratoire d'intégration des technologies de production (LITP) since 2002. Professor Nadeau's research and development efforts focus primarily on the management of health and safety risks, integrated risk management and the prevention of musculoskeletal disorders. She has been developing a prototype information system and risk management model adapted to organizations where autonomous and polyvalent work prevails, an innovative model integrating equipment lockout/tagout with production planning, a non linear and elastic model using the pressure vessel theory to explain the discal hernia mechanism. Her main industrial collaborators include STIQ (Sous-traitance Industrielle Québec), Tecsult EduPro, Pratt & Whitney Canada, Bombardier, Via Rail Canada and Canadian Gypsum.

Jean-Pierre Kenné is professor in the department of mechanical engineering and director of the Laboratory of Integrated Production Technologies (LIPT). He received a bachelor degree in mechanical engineering from the university of Douala in 1984. He received Master and Ph.D degrees in mechanical engineering from Ecole Polytechnique of Montreal respectively in 1991 and 1997. He has been with GEBO Canada and Logitrol as a project manager in automation in 1998 and 1999 respectively. . He joined the department of mechanical engineering, Ecole de technologie superieure, in 2000 where he is teaching control theory, fluid power systems, design and control of manufacturing systems courses. His research interests are in nonlinear control, capacity planning, control of manufacturing systems and optimization of production systems performances.

Paul Alexandru is an engineering consultant in Romania. He received his Ph.D. at École de technologie supérieure in Montreal in 2009.