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ECONOMIC IMPACT OF OCCUPATIONAL ACCIDENTS: RESOURCE ALLOCATION FOR AUVA'S PREVENTION PROGRAMS

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Abstract - Occupational injuries are a great burden on health care costs worldwide. We present the first detailed analysis of the total direct and indirect costs of individual occupational injury claims for a given year covering costs for: a general injury insurance company, the AUVA, employers, and the Austrian economy. We calculated total lifetime costs discounted by 3% of 543, 228, and 927 million Euro for the AUVA, employers, and the economy, respectively. Using Classification and Regression Trees, all patients are clustered into risk groups according to several criteria such as age, gender, and job type with similar resource needs, e.g., lifetime pension costs. At the end, we present cost-effectiveness thresholds for prevention program costs per injury for certain risk groups. Our investigation helps the AUVA not only to allocate its prevention budgets optimally, but also to politically argue that its budget should not be reduced for the purpose of subsidizing other social security companies.

KEYWORDS - Classification and regression trees (CART); decision support system; cost-effectiveness analysis; resource allocation; prevention; occupational injuries

INTRODUCTION

At the onset of the twenty-first century, unsafe and unhealthy working conditions still take a heavy human and economic toll(1). Leigh et al.(2) conservatively estimated that approximately hundred million occupational injuries (100,000 deaths) and 11 million occupational diseases (700,000 deaths) occur worldwide each year. There are high direct costs such as medical and insurance administration expenses and indirect costs such as lost earnings, lost home-based production, and lost fringe benefits of occupational injuries and illnesses(3).

In the United States of America, for example, approximately 6,500 job-related deaths from injury, 13.2 million nonfatal injuries, 60,300 deaths from disease, and 862,200 illnesses were estimated to occur annually in the civilian workforce(3). These occupational injuries and illnesses raised total direct (US$65 billion) plus indirect (US$106 billion) costs, while the majority of US$145 billion was related to occupational injuries.

In Austria, with about 8 million inhabitants, the total number of occupational injuries significantly dropped from ca. 165,000 (304 deaths) in the year 1995 to ca. 132,000 (215 deaths) in the year 2000(4). In 1994, it was estimated that occupational injuries incurred both direct and indirect costs of ca. 1.8 billion Euro(5).

However, occupational injuries and illnesses still remain an under-appreciated contributor to the total burden of health care costs worldwide(2). According to the International Labor Office(1), promoting prevention

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strategies targeted towards occupational injuries should be policy makers' main aim in the next several years. Not only will the number of injuries drop, but also insurance companies, employers, and the economy will benefit from such programs.

Despite massive improvements in social, safety, and occupational standards for the Austrian workforce, occupational injuries still cause enormous distress and disability. For this reason, the Allgemeine Unfallversicherungsanstalt (AUVA - General Injury Insurance Company) – the main compulsory social insurance company in Austria with nearly three million insured employees, 1.3 million primary, secondary, and university students, as well as numerous staff of relief and rescue organizations – wanted to investigate the direct and indirect costs of occupational injuries in more detail. The AUVA's policy makers aimed at selecting cost-effective prevention strategies targeted towards certain risk groups. Thus, we developed a decision-support system for the investigation of occupational injuries for the AUVA that consisted of 1) a cost calculation tool and 2) a tool to analyze major risk groups and the costs incurred.

A structure for the costs of occupational injuries covering costs for the AUVA, employers, and the economy was derived from the literature. The AUVA cost structure for occupational injuries was investigated in detail and payment rules were established. The main AUVA costs cover pension payments, allowances, funeral costs, hospitalization costs, costs for prostheses, rehabilitation costs, and transportation costs. For the first time, nearly all direct and indirect costs of the past, present, and future were calculated by using individual injury data from year 2000. These injuries would lead to lifetime costs of about 543 million Euro for the AUVA (discounted by 3%). Furthermore, main costs for the employers (about 228 million Euro) and the economy (about 927 million Euro) were also calculated (discounted by 3%). In total, the injury cases of 2000 would lead to lifetime costs of about 1,699 million Euro (discounted by 3%).

We provided the AUVA with a software program, PORT, which is based on classification and regression trees (CART) to cluster groups of patients with similar resource needs according to several criteria (e.g., age, gender, job types, economy class). For the first time, the AUVA can identify high-risk groups for whom high costs are incurred. We illustrated that the AUVA can select an appropriate tree based on a dependent variable of interest for them (e.g., lifetime pension costs). For example, by investigating the features of risk groups, the AUVA is able to focus on prevention programs for the risk group with the highest costs per patient or for the risk group with the highest number of injuries. Finally, we presented cost-effectiveness thresholds for prevention program costs per injury for certain risk groups. Our investigation not only helps the AUVA optimally allocate its prevention budgets but also strengthens their political argument that their budget should not be reduced for the purpose of subsidizing other social security companies.

METHODS

The General Classification Problem

As a direct consequence of individuality, patients differ in a number of medical, physical, and socio-economic characteristics, for example by age, profession, severity of an accident in the workplace, time off work, and speed of recovery. Resulting resource needs and corresponding costs vary from patient to patient. From both a clinical and operational perspective, it is desirable to be able to divide this heterogeneous group into smaller homogeneous (in terms of some measure) sub-groups. Homogeneity brings the benefits of increased certainty in individual patient needs and resource utilization. For example, given an individual patient, we can classify him/her into a patient sub-group in which we know with a given confidence from past experience and data, that his/her risk of an accident at work is likely to be within a certain range of likelihood. The risk or costs for this population group will typically substantially differ from the predicted risk and costs of other groups. The purpose of classification in this example would be to produce tight bands with high confidence. Thus, with the added knowledge and confidence of risk of injury and expected costs, the potential for improved efficiency and effectiveness in targeted interventions is considerable.

An important criterion for a good classification procedure is that it not only produces accurate classifiers (within the limits of the data) but that it also provides insight and understanding into the predictive structure of the data(6). For example, finding which characteristics contribute to the risk of an injury in the workplace not only provides valuable assistance in assuring some certainty in the classifying of individuals into risk groups, but more generally has advanced the knowledge and understanding of who is at higher risk of injury.

A general classification problem consists of two main elements. Measurements are made on some case or object – such as a patient who has had an accident – with measurements including age, sex, profession, type of injury, hospital treatment, time off work, injury severity, etc. Based on these measurements a prediction is made about the class of the case. The prediction is made following a pre-defined classification rule.

In mathematical terms, we define X to be the measurement space containing $x = (x_1, x_2,\ldots,x_m)$, , the measurement vector, where each x_i is a measurement taken on a case. The method should, given any x in X, have a classification rule to assign one of the classes $(1,2,3,\ldots,J)$ to x, where J is the number of classes. The classifiers are based on past experience using a combination of expert knowledge and past data with their relevant outcomes. For example, the classifiers to be defined could come from the AUVA database combined with the expert knowledge of the AUVA managers and medical staff.

Comparison of Classification Algorithms

Many different classification algorithms exist such as regression models, tree-based algorithms, Artificial Neural Networks (ANN), and Discriminant Analysis (DA). Intrasubject comparisons have been considered in the past, for example, within statistics(7), within symbolic learning(8) and within neural networks(9). Other authors, for example, King et al.(10) and Harper(11) have compared different algorithms for different types of data-sets. The algorithms were evaluated using a number of criteria to measure the accuracy and the computing time taken to produce results, the comprehensibility of the results, as well as the ease of use of the algorithm to relatively naïve users.

Research in this area indicates that we don't have a single best classification tool in practice but instead, the best technique will depend on the features of the data-set to be analyzed and any end-user preferences. CART however has shown to be particularly robust and user-friendly(10,11). This is a measure of the extent to which the CART algorithm performs over a range of different data-sets, produces comprehensible results that are generally easier to interpret than the results of other algorithms, as well as on the time it takes for policy makers to understand the technique, prepare the data, and actually perform the analysis to produce correct and meaningful results.

Classification and Regression Trees

Classification and Regression Trees is a classification method that has been used successfully in many healthcare applications. Example applications include those in minimum data requirements(12), cancer survival groups(13), intensive care(14), and hospital bed capacities(15).

The first step in producing a tree is to decide which variable is to be predicted, for example survival rates and days off work. If the variable is ordinal then the variance is used to measure the purity in the group, if the variable is categorical then deviance is used. An algorithm is used to split the original data-set into sub-populations of increasing purity (decreasing variance or deviance) at each junction of the tree is a node. A terminal node is a node at the end of the branch of the tree. At each node in the tree, the algorithm searches through each of the independent variables in turn. For each variable, it finds the best binary split that produces a node with the smallest variance or deviance. It then selects the variable that has produced the best binary split (best of the best). The parent node will thus be split on this variable with the split as defined. This may have the effect of leaving one of the child nodes with a higher variance/deviance than the parent node. The algorithm however continues to branch from each of these child nodes until defined stopping rules have been fulfilled. Stopping rules include: stop when nodes contain a certain number of cases; stop when reduction of variance is below a certain threshold; stop when a maximum number of terminal nodes (or layers) have been produced.

A statistical package, PORT, has been developed at the University of Southampton, United Kingdom. PORT incorporates a tree-based algorithm, similar to CART, that assists in the production of clinically and statistically meaningful healthcare groupings. For example, such healthcare groupings could be patient groupings based on cost of injury, time off work, or severity of injury. We have adopted the PORT software for our purposes and it was the first time that it was applied to predict detailed costs for occupational injuries. PORT has been designed to enable AUVA policy makers to create appropriate groupings of cases and carry out the necessary statistical analysis. At the highest level of functionality, PORT may be used as a:

- Data exploratory tool, allowing the user to explore and understand in greater detail their data. For example, PORT permits manual splitting of the data into desired groupings and the rapid extraction of a number of key statistics, time-dependent profiles, and continuous distribution fitting.
- Tree-based algorithm tool for classification and prediction, allowing the policy maker to derive statistically meaningful, easy to interpret homogeneous groupings. This aids understanding of the structure of the data, enabling the policy maker to define interpretable classification rules as necessary.

Cost Calculating Tool and Data

Data was provided on all acknowledged claims in 2000 with injury dates mostly in 2000 and some in 1999 and earlier. In total, 123,387 cases were contained within the database and 66 features of occupational injuries were created to capture information on each case (see table 1). Of these cases, 3,902 were retirees who received a pension or whose dependents received a pension in the case of a fatal injury.

We gathered 1) demographic information on the patient such as sex, date of birth, and age; 2) injury information on the patient such as injury number, year of accident, and date of accident; 3) the patient's employer information such as zip code, account number, and number of employees; 4) treatment information on the patient such as kind of treatment received, place of treatment, and initial date of illness; and 5) AUVA cost information per patient such as kind of pension, disability support, and child allowance. We used complex rules governing the cost calculations of each cost category to calculate from the demographic, employer, injury, treatment, and cost information of the AUVA; 6) the AUVA costs such as pension costs, allowances cost, and funeral costs, 7) employer costs, and 8) costs to the economy such as production lost at work and in the household, as well as direct injury costs (e.g., salaries)(16). We did not consider costs for patients (such as pain, loss of leisure time) as these costs are controversial and difficult to determine(17).

Table 1: Database fields used in the cost calculating tool

Demographic Information	**Employer Information**
Sex[23]	Zip Code of Employer[23]
Date of Birth[23]	Account Number of Employer[23]
Age[23]	Number of Employees[23]
Life Expectancy[23, 24]	Economic Class[23]
Nationality[23]	Job Type[23]
Social Security Number[23]	Job Grade[23]
Date of Birth of Relative(s)[23]	Job Class[23]
Sex of Relative(s)[23]	Employment Status[23]
Age of Relative(s)[23]	Salary (calculated)[23, 25]
Probability of Being Married Now[23, 24]	
Probability of Being Married at Death to the Same Partner[23, 24]	
Injury Information	**Treatment Information**
Injury Number[23]	Kind of Treatment Received[23]
Year of Accident[23]	Place of Treatment[23]
Date of Injury[23]	Initial Date of Illness[23]
Week Day of Injury[23]	End Date of Illness[23]
Day of Injury[23]	Days off Work[23]
Time of Injury[23]	
Place of Injury[23]	**AUVA Cost Information**
Kind of Injury[23]	Kind of Pension[23]
Part of Body Injured[23]	Amount of Pension[23]
Side of Body Injured[23]	Disability Support[23]
Reason for Injury[23]	Child Allowance[23]
Severity of Injury[23]	
Disability Class[23]	
AUVA Costs Calculated	**Employer Costs Calculated**
Pension Costs[23, 24, 26-29]	Employer Costs[18, 19, 23, 30, 31]
Allowances Costs[23-28]	
Funeral Costs[23, 25, 26]	**Economy Costs Calculated**
Hospitalization Costs[23, 32-35]	Production Loss (Work)[18, 19, 23-25, 30, 31]
Prostheses Costs 2000[23, 32, 33, 36, 37]	Production Loss (Household)[23, 24, 38]
Prostheses Costs 2001[23, 32, 33, 36, 37]	Direct Injury Costs (e.g., Salaries)[18, 19, 23, 30, 31]
Other Prostheses Costs[23, 32, 33, 36, 37]	Sick Pay Costs[23, 39]
Total Prostheses and Other Devices Costs[23, 32, 33, 36, 37]	
Rehabilitation Costs 2000[23, 32-34, 36, 40]	
Rehabilitation Costs 2001[23, 32-34, 36, 40]	
Total Rehabilitation Costs[23, 32-34, 36, 40]	
Prevention and First Aid Costs[32, 33]	
Transportation Costs[23, 24, 41, 42]	
Costs for Special Doctors and Other Care[32, 33]	
Payment Fees[32, 33]	
Administration Costs[32, 33]	
Depreciation[32, 33]	
Other and Extraordinary Costs[32, 33]	
Allocation to Reserves[32, 33]	

The cost calculating tool was designed and built within MS-Access linking to the data source. It is easy to use and allows maximum flexibility, for example in permitting changes to default parameter values. The tool calculates both past and future costs (for a year, a period, or life time) to the AUVA, the employer, and the economy. Inflation and discounting rates have been included and policy makers may calculate costs over a specified period (e.g., a year or a range of years) or the lifetime costs for a cohort of patients. We used an inflation rate for pensions/salaries and goods of 3.59% and 2.3%, respectively(18).

For example, to calculate AUVA pension costs for patients and in the case of fatal injuries, for their dependents such as widows or widowers, orphans, parents, and brothers and sisters, we had to incorporate complex payment rules such as eligibility for pension, amount of pension, and years of pension to be paid. For young dependents a pension was paid only during their education or training up to a certain age.

Some of the AUVA data such as data on prostheses and other devices as well as rehabilitation were available in an incomplete and unstructured form in databases and written guidelines scattered throughout different departments of AUVA's organization. We were able to derive future costs for prostheses and other devices based on cost data in the years 2000 and 2001 and also based on informal replacement guidelines (most of the main prostheses were replaced every six years). Unfortunately, at the present time the AUVA only reports the company names from which they bought prosthetic devices and not the name of the device they bought. Rehabilitation costs include stays in rehabilitation centers, occupational rehabilitation (e.g., education, training), and social rehabilitation (e.g., remodeling of houses, special cars for the disabled). Using past data on rehabilitation costs and reports on visits to rehabilitation centers, we estimated future rehabilitation costs.

To calculate the company costs, we used a formula for direct injury costs for companies developed by the AUVA(19). This formula is based on gross wages, ancillary wage costs, an economic class factor (e.g., a high factor for industrial production because of shutdown of production lines, a lower factor for trade), and the number of hours of sick leave due to the injury. We further incorporated that from 1 October 2000 the wages of the patients had to be paid by the company, while before that time a fund paid the wages.

We took into consideration the main economic costs such as loss of productivity at work and at home due to injuries, direct costs of the injury such as salary payments for patients before 1 October 2000, and sick pay. For example, while male patients have a higher loss of productivity at work due to higher salaries of men in comparison with women, female patients have a higher loss of productivity in the household due to their higher share in housework in comparison with men.

Once the model has been run with the user-chosen parameters, a report summary, which may be printed, shows a breakdown of all costs in each category. The results may also be exported for use in CART classification software.

To summarize; for the first time in the literature, past and future occupational costs of an insurance company were estimated in great detail providing a powerful decision support system for policy makers. Furthermore, the major company and economic costs were also considered. In a taxonomy for occupational injury costs, we provide comprehensive illustration of which costs for insurance companies, company, economy, and patients (such as pain, loss of leisure time) were calculated or discussed in international studies in the past(20). For example, compared to the most recent and accurate study by Bensch(5) on occupational injury costs in 1994 for Austria, we had data per injury case and not just aggregated data for three accident categories such as fatal injuries, heavy injuries, and light injuries. For this reason, in the past the AUVA was unable to derive accurate prevention strategies. Moreover, Bensch(5) did not account for future costs such as rehabilitation costs, costs for prostheses and other devices, and pension costs. Furthermore, we incorporated more AUVA costs such as pension costs, assurance costs, funeral costs, cash benefit during treatment, costs for prostheses and other devices, detailed rehabilitation costs, occupational and social rehabilitation, and detailed transportation costs. We considered direct company costs (e.g., salaries), while Bensch5 accounted only for indirect costs such as property damage for companies. We calculated economic costs rather similarly to Bensch5, however, we also included costs for sick pay and direct injury costs such as salaries to be paid.

Results and Policy Implications

We currently use our approach with a model that offers comprehensive evaluation of the costs and details of occupational injuries. We then investigate risk groups for potential prevention programs and, in conclusion we illustrate cost-effective prevention programs for these risk groups mainly from an AUVA perspective.

Total Costs for Occupational Injuries

Using the cost calculation tool, we calculated several cost scenarios for the AUVA, the companies, and the economy by varying the discount rate between 0% and 5% (see table 2). We provide results for a discount rate of 3.21% to make results comparable to a rough study by Bensch(5). As policy makers are interested in past, current, as well as future costs, we determined costs for the past (years 2000-2001), the next five years (years 2002-2006), and for lifetime costs of occupational injuries. The costs of occupational injuries are a particular burden on both the economy and the AUVA. Total lifetime costs would amount to between 1,330.4 and 2,867.9 million Euro for a 5% and a 0% discount rate, respectively.

Table 2: Total costs of occupational injuries that were incurred for the AUVA, companies, and the economy

	Costs in Euro			
	AUVA	Companies	Economy	Total
Discount rate 0%				
Years 2000-2001	90,727,348	235,561,998	279,710,639	605,999,985
Years 2002-2006	68,765,290		159,902,508	228,667,799
Lifetime	1,157,587,616	235,561,998	1,474,797,709	2,867,947,324
Discount rate 3%				
Years 2000-2001	87,837,408	228,495,138	270,447,396	586,779,942
Years 2002-2006	59,389,541	0	137,273,410	196,662,951
Lifetime	543,435,348	228,495,138	926,783,987	1,698,714,473
Discount rate 3,21%				
Years 2000-2001	87,628,905	228,000,458	269,800,987	585,430,351
Years 2002-2006	58,728,906	0	135,800,627	194,529,533
Lifetime	521,563,290	228,000,458	901,719,350	1,651,283,098
Discount rate 5%				
Years 2000-2001	85,909,710	223,783,897	264,301,848	573,995,454
Years 2002-2006	53,638,265	0	123,800,311	177,438,576
Lifetime	376,206,521	223,783,897	730,439,868	1,330,430,287

The effects on the economy are the greatest (about 51.4% of non-discounted total lifetime costs). For the scenarios with 0% discounting (see table 3), salary payments during sick-leave of up to 8 to 10 weeks (about 154.1 million Euro), payments for sick pay for up to 26 weeks for patients who get a pension and up to 52 weeks for patients who do not get a pension (about 65.5 million Euro), and productivity loss at work (about 52.2 million Euro) represented the highest costs in the past (years 2000-2001). Salary Payments during sick-leave and for sick pay were incurred soon after the injury, while productivity loss at work or at home were incurred up to the pension age or lifelong, respectively. As the past costs (years 2000-2001) represent about 19% of the lifetime costs, a discount rate of 5% compared to 0% would decrease the lifetime costs of the economy by about 50% (from 1,474.8 to 730.4 million Euro - see table 2). The lower the share of non-discounted past costs in a category's total costs, the lower the discounted lifetime costs. Thus, the companies' lifetime costs would decrease by about 5% when discounted by 5% because all of these costs were incurred in the past (years 2000-2001).

Table 3: Detailed lifetime costs for the AUVA, companies, and economy discounted by 3%

Affected Area	Cost category	Costs in Euro
AUVA	Pension costs	24,273,268
	Allowances	0
	Funeral costs	504,634
	Hospitalization costs	53,842,033
	Costs for Prostheses and other devices	494,209
	Rehabilitation costs	3,234,968
	Costs for prevention and first aid	1,322,306
	Transportation costs	673,873
	Costs for special doctors and other care	624,102
	Payment fees	25,46
	Administration costs	2,034,254
	Depreciation	957,968
	Other and extraordinary costs	2,709,724
	Allocation to reserves	30,55
	Total Costs	**90,727,348**
Companies	**Total Costs**	**235,561,998**
Economy	Productivity loss (work)	52,223,010
	Productivity loss (household)	7,872,018
	Direct costs of the injury (e.g., salaries)	154,120,565
	Sick pay	65,495,046
	Total Costs	**279,710,639**
AUVA Companies Economy	**Total Costs**	**605,999,985**

Occupational injury costs also highly burden the budget of the AUVA. About 7.8% of the non-discounted costs were incurred in the past (years 2000-2001) as shown in table 2. The past costs of the AUVA mainly consisted of hospitalization costs (about 59.3%) and pension costs (about 26.8%). Future costs (years 2002-2006) would be almost entirely pension costs (about 90.1%). Discounting the AUVA's lifetime costs by 5%, would decrease the AUVA's non-discounted lifetime costs by about 67.5%. As the AUVA's lifetime costs dropped more compared to the economy's or companies' costs by discounting costs, the share of the AUVA's lifetime costs in total costs decreased from about 40.4% without discounting to about 28.3% with a discount rate of 5%.

Companies were least affected by occupational injury costs because payments for sick-leave salaries and short-term breakdown costs, for the most part, have to be paid for several weeks after the injury. Thus, the share of the companies' costs was about 38.9% in non-discounted total costs for the years 2000-2001. In contrast, the share of companies' lifetime costs amounted to about 8.2% and 16.8% in non-discounted and 5% discounted total costs, respectively.

To summarize, our total cost investigation of occupational injuries illustrated that in particular the overall economy and the AUVA would benefit from prevention programs initiated by the AUVA. However, companies should also be interested in cooperating with the AUVA prevention team because of their high share in costs that are incurred soon after the injury. In a next step, we investigated the features of the main risk groups for the AUVA by using the PORT software to help the AUVA select risk groups for potential prevention strategies.

Regression Tree Analysis for Occupational Injuries

For the lifetime costs of the AUVA, pension and rehabilitation costs represent the highest cost factors (see table 3). As pension costs represent about 65% of total lifetime costs discounted by 0%, we investigated the group of AUVA's pensioners (3,902 cases) in more detail. Thus, we chose pension costs as our dependent variable. The list of independent variables included age, sex, nationality, week day of injury, time of injury, place of injury, economic class, number of employees, employment status, job class, job type, job grade, kind of injury, part of body injured, kind of treatment, place of treatment, days off work, injury severity, and number of accidents per individual. We assumed a 3% discount rate. Furthermore, we restricted the analysis to 15 final groups, a minimum of 50 cases per group, a maximum of 1,000 total groups, and a 0.001% significance level.

Figure 1 shows the resulting classification tree. Beside each non-terminal node the independent variable responsible for the classification is listed. For example, the first split is made based on the patient's number of days off work. Patients with less than 236 days off work are classified to nodes on the left side, while the others are grouped to the right nodes. For numerically independent variables such as the number of days off work, we indicate the range for the values beside the arrows. The final risk groupings with their mean pension costs are found as terminal nodes (nodes which are not further split) such as node #8 with pension costs of 36,360 Euro per case. Below the pension costs, the number of cases for each node are listed in parentheses. For example, terminal node #17 was the largest group with 1,124 cases, while node #23 was the smallest group with 51 cases.

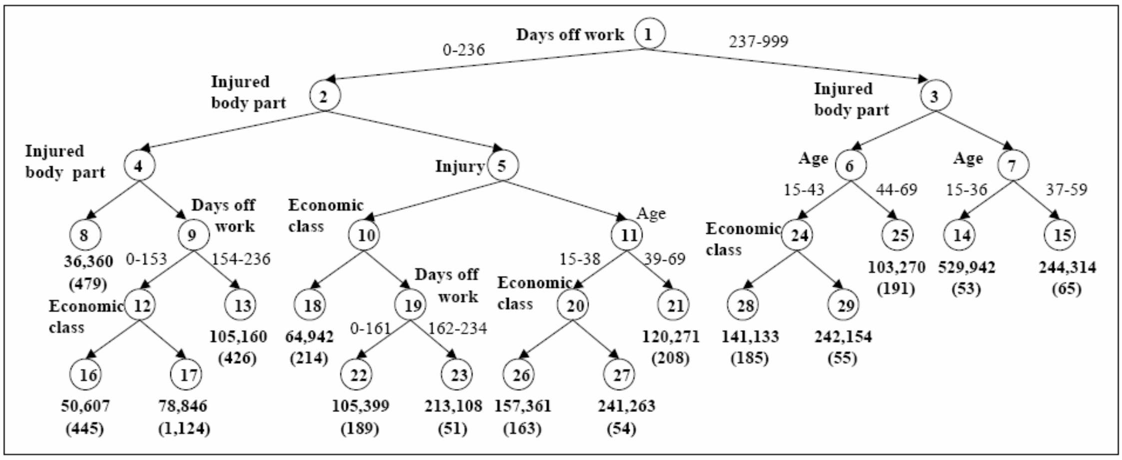

Figure 1: Risk groups for the AUVA's lifetime costs discounted by 3% (dependent variable was pension costs)

The important variables for splitting nodes include: numbers of days off work, injured part of body, kind of injury, age, and economic class. Thus, the AUVA policy makers should focus on these key variables if they are interested in lifetime pension costs discounted by 3%. For example, the lowest pension costs were incurred for 479 patients who were off work less than 237 days and whose injured body parts included minor injuries such as fingers, knee, toes, ears, arms, and legs. Thus, the mean disability rate for this risk group was about 20.4%, which provoked low costs. In contrast, the highest costs were caused by 53 young pension cases age 15-36, who were off work for more than 237 days and had major bodily injuries (e.g., spinal, brain, multiple injuries). This group's high mean disability rate of 65.7% together with its young age caused the highest lifetime pension costs of 529,942 Euro per case.

Risk Groups for Potential Prevention Programs

To focus intervention strategies on certain risk groups, the AUVA policy makers could now analyze in more detail the features of each node such as terminal node #14, the highest risk group aged 15-36 with more than 237 days off work. In this group were ca. 86% Austrian citizens, 87% males, and 76% blue collar workers. The share of 17 year olds in this group, about 11%, was rather high. About 98% of this group survived and terminated their work. Many injuries occurred on Mondays (22.6%) or on Fridays (18%). Furthermore, about 13% of the injuries occurred at 5 p.m. and about 81% of this group had travel accidents or assembly accidents outside the ordinary workplace. About 49% and 21% of these cases had jobs in transportation and construction, respectively. Most of these patients had injuries such as closed fractures (about 38%) or contusions (about 26%). As mentioned before, these patients had major injuries such as spinal (about 43%) or brain (25%). Nearly all cases were treated within 3 days after injury with a hospitalization rate of ca. 70%. In 51% of the cases, the job grade was skilled worker. In addition, about 36% and 26% of this group were employed in production (mining and construction) as well as in industry, respectively. With all this information in mind, the AUVA can set up focused prevention strategies for this target group such as programs focused on young blue collar workers 1) in construction and 2) in traffic. This risk group causes about 28.1 million Euro of total lifetime pension costs for the AUVA.

However, the AUVA may also want to target intervention strategies for the risk group with the most cases, terminal node #17 with 1,124 pension cases. This group causes about 88.6 million Euro of total lifetime pension costs. This is about three times the amount of risk group #14. Furthermore, this group is responsible for about 23% of the total lifetime pension costs for the AUVA.

In contrast to risk group #14, in risk group #17 most of the injuries occurred at work (about 67%) or at assembly (31%). In this group, we found less cases of severe injuries with an average disability rate of 20.45% and less than 154 days off work (see figure 1). Nearly all of these patients were treated within less than three days after the injury in a hospital (about 56% hospitalization rate). About 88% of these cases were blue-collar workers, male and about 80% were Austrian citizens. About 92% injured their fingers: 24% right finger injuries, 20% left finger injuries, 14% left thumb injuries, 12% right dumb injuries, and 18% multiple finger injuries. Most of these injuries occurred in construction (ca. 24%) or in industrial or commercial production such as furniture, jewelry, music, and sports equipment production (ca. 9%); metal production (8%); mechanical engineering (ca. 7%); and timber processing and production without furniture production (ca. 7%). Most of these cases worked with (ca. 48%) or on (ca. 16%) machines, motors, or devices. The job grade of these cases was: 49% skilled workers, 26% semi-skilled workers, and 16% unskilled workers. More than 99% of these cases terminated their work after the injury, whereby about 39% and 31% of the injuries happened during 8 a.m.-12 p.m. and 12 p.m.- 4 p.m., respectively. The peak hour of injuries was 11 a.m. (about 11%). This analysis shows, that prevention strategies could focus on lowering the risk of finger injuries in construction as well as in industrial and commercial production 1) by introducing more breaks to reduce signs of fatigue, 2) by promoting the usage of protective gloves, 3) by using saver machines, motors, or devices; and 4) by general counseling programs on occupational safety.

Cost-Effective Prevention Programs for Risk Groups

In a next step, we evaluated cost-effective prevention programs for risk group #14, the highest cost group, and risk group #17, the group with the most cases. To calculate cost-effectiveness ratios (CRs) for prevention programs, we have to divide the additional discounted costs plus prevention program costs per averted injury case by the additional discounted QALYs gained per averted injury case.

The additional discounted costs per averted injury case include all AUVA cost components listed in table 3 excluding costs for prevention and first aid, administration costs, depreciation, other and extraordinary costs, as well as allocation to reserves as these costs were incurred by all individuals insured by the AUVA. For our cases who deceased, the full remaining life years were lost (see equation 1), while for our cases, who were disabled, there was a loss in the quality of life for their remaining life years depending on their disability rate (see equation 2):

$$CR\ (Cases\ Deceased) = \frac{\begin{array}{c}Average\ Addidional\ Discounted\ Lifetime\ Costs\ per\ Case + \\ Prevention\ Program\ Costs\ per\ Case\end{array}}{Average\ Discounted\ Years\ of\ Life\ Lost} \qquad (1)$$

$$CR\ (Cases\ Alive) = \frac{\begin{array}{c}Average\ Addidional\ Discounted\ Lifetime\ Costs\ per\ Case + \\ Prevention\ Program\ Costs\ per\ Case\end{array}}{Average\ Discounted\ Years\ of\ Life\ Lost \cdot \frac{Average\ Disability\ Rate}{100}} \qquad (2)$$

Thus, we had to distinguish between men and women as well as between pension cases who died soon after the injury and those who did not die. Therefore, we further investigated our risk groups #14 and #17 by splitting these groups by sex and by survival. Table 4 illustrates the number of cases, the average disability rate, the average age, the average discounted years of life lost due to disability, and the average additional life time AUVA and total costs per case for our risk groups. We discounted both costs and effectiveness by a 3% discount rate (21). For example, we had 46 cases of men alive in risk group #14 with an average age of 26.8 years and an average disability rate of 65%. These men lost on average 47.25 years of disability-free life with average additional AUVA or total life-time costs per case of 628,907.15 or 1,289,608.32 Euro.

Table 4: Analysis of average disability rate, average non-discounted and discounted life years without disability lost as well as average additional discounted AUVA and total lifetime costs per case in different risk groups

Risk Group	No. of Cases	Average Disability Rate	Average Age	Average LifeYears Lost per Case	Average Discounted LifeYears Lost per Case	Average Additional Discounted AUVA Life Time Costs per Case	Average Additional Discounted Total Life Time Costs per Case
Risk Group #14, Men Alive	46	65.00%	26.80	47.25	25.09	628,907.15	1,389,608.32
Risk Group #14, Women Alive	7	70%	24	55.96	26.96	488,897.24	1,526,379.66
Risk Group #17, Men Alive	958	21.03%	38.09	36.61	22.04	121,787.99	288,897.87
Risk Group #17, Men Dead	16	23.13%	44.75	30.52	19.81	117,698.15	375,669.22
Risk Group #17, Women Alive	150	20.83%	42.59	37.94	22.47	83,441.70	219,459.78

As we could not directly relate a disability rate of 0.65 for a life year to a QALY of 0.35, we calculated ranges for this conversion (80% to 120%). Thus a disability rate of 0.65 for a life year might relate to a QALY of 0.28 to 0.42. We assumed a willingness-to-pay threshold of 50,000 Euro per QALY(22).

For one averted case in risk group #14, we would gain between 13.04 and 19.57 QALYs. Thus, the AUVA could spend a prevention budget per averted injury case of up to between 1,208,122.55 and 1,607,230.24 Euro or between 2,041823.72 and 2,367,931.42 Euro per QALY to be cost-effective for AUVA costs or for total costs, respectively (see table 5 and figure 2). For low prevention program costs per case, these prevention strategies would even save money as illustrated in the columns for highly cost-effective prevention budgets. In such a case, the CR<=0. For example, prevention programs with AUVA costs up to 628,907.15 Euro per averted male injury case in risk group #14, would even save costs for the AUVA (see table 5 and figure 2). If total costs to the economy were considered, then up to 1,389,608.32 Euro per averted male injury case in risk group #14 would be highly cost-effective.

Table 5: Analysis of the range for QALYs gained per averted injury case as well as cost-effective and highly cost effective prevention budget per averted injury case for the AUVA and total costs in different risk groups

Risk Group	QALYs	Cost-Effective Prevention Budget per Case (AUVA Costs)	Highly Cost-Effective Prevention Budget per Case (AUVA Costs)	Cost-Effective Prevention Budget per Case (Total Costs)	Highly Cost-Effective Prevention Budget per Case (Total Costs)
Risk group #14, Men Alive	13.04 - 19.57	1,281,122.55 - 1,607,230.24	<=628,907.15	2,041,823.72 - 2,367,931.42	<=1,389,608.32
Risk group #14, Women Alive	15,10 - 22,64	1,243,716.26 - 1,621,125.77	<=488,897.24	974,278.80 - 1,351,688.31	<=1,526,379.66
Risk group #17, Men Alive	3.71 - 5.56	307,159.81 - 399,845.71	<=121,787.99	474,269.68 - 566,955.59	<=288,897.87
Risk group #17, Men Dead	15.85 - 23.77	910,035.53 - 1,306,204.23	<=117,698.15	1,168,006.60 - 1,564,175.30	<=375,669.22
Risk group #17, Women Alive	3,74 - 5,62	270,686,30 - 364,308,60	<=83,441.70	406,704.38 - 500,326.68	<=219,459.78

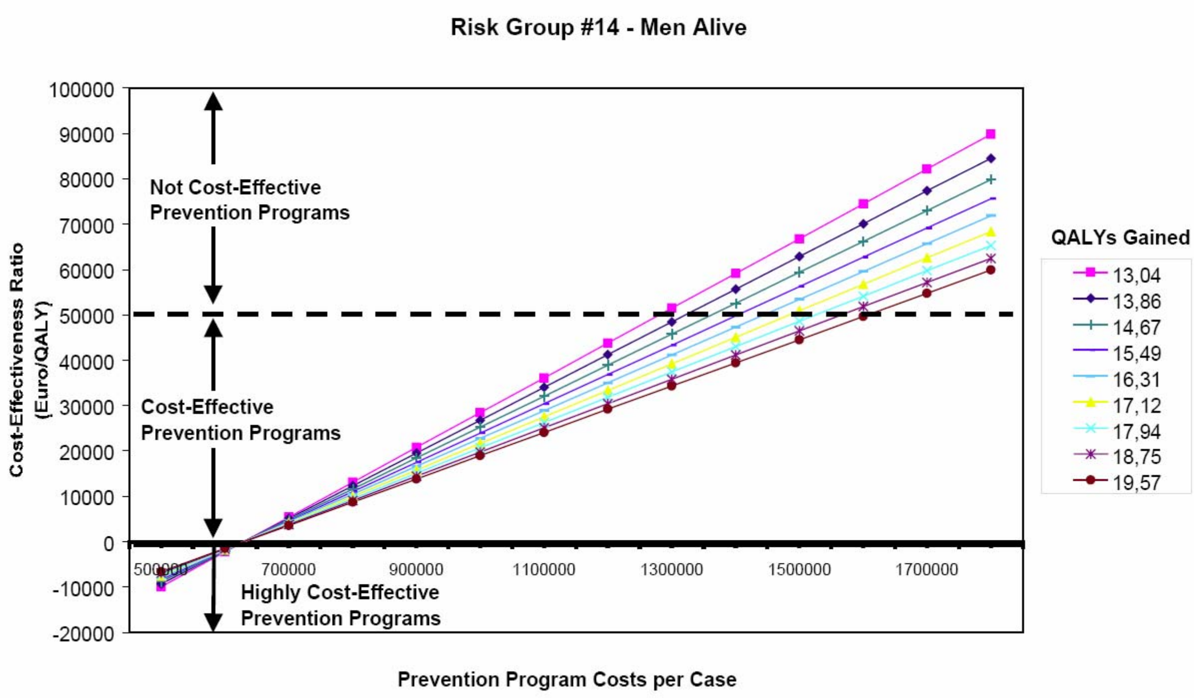

Figure 2: Illustration of cost-effective prevention programs depending on prevention program costs and QALYs gained per averted male injury case in risk group #14

DISCUSSION AND FURTHER RESEARCH

In this study, we analyzed the economic impact of occupational injuries for an insurance company, the AUVA, as well as the employers and economy in Austria. For the first time, nearly all direct and indirect costs of the past, present, and future were calculated by using individual injury claims from year 2000. These calculations are done in a cost calculating tool, incorporating complex cost calculating rules whilst permitting the user to change a number of default variables and parameters for scenario analysis. The tool has been designed with flexibility and user-friendliness in mind.

We calculated that total lifetime costs would amount to between 1,330.4 and 2,867.9 million Euro for a 5% and a 0% discount rate, respectively. Our results show that both the AUVA and the economy were most affected. About 51.4% and 40.4% of the non-discounted total costs were incurred by the AUVA and the economy, respectively. Thus, prevention strategies initiated by the AUVA would be highly beneficial to the economy and also to some extent for companies. For the AUVA, hospitalization costs and pension costs were the main driving forces for past costs (years 2000-2001), while pension costs comprised nearly the entire total future costs of occupational injuries. Companies were least affected by occupational injury costs because payments for sick-leave salaries and short-term breakdown costs mainly have to be paid for several weeks after the injuries. If we discounted the total costs by 5%, the share of the companies' costs in total costs would heavily increase from 8.2% to 16.8%, the share of the economy's costs in total costs would rise slightly from 51.4% to 54.9%, and the share of the AUVA's costs in total costs would decrease heavily from 40.4% to 28.3%. The reason for this effect can be explained by the chronological accrual of costs. As the costs for companies and the economy are incurred soon after the injury compared to the AUVA, their share in total costs increase by discounting.

To support the AUVA's selection of target groups for prevention strategies, a statistical package, PORT, has been adopted which incorporates a CART based algorithm that assists in the production of clinically and statistically meaningful groupings. For example, these could be groupings based on lifetime pension costs, the main costs for the AUVA.

For the risk group with highest lifetime pension costs per case discounted by 3% (about 529,000 Euro), the AUVA should focus on prevention strategies for young male blue-collar workers 1) in construction and 2) in traffic. We assumed a willingness-to-pay threshold of 50,000 Euro per QALY. These prevention programs would be cost-effective for prevention budgets per averted injury between about 1.3 and 1.6 million Euro or 2 and 2.4 million Euro from an AUVA or total economy angle, respectively, that gain about 13 to 20 QALYs.

However, the AUVA may also want to target intervention strategies to the risk group with the most cases (1,124 pension cases) and total lifetime pension costs per case of 78,846 Euro discounted by 3%. For this risk group, AUVA prevention strategies could focus on lowering the risk of finger injuries in construction as well as in industrial and commercial production 1) by introducing more breaks to reduce signs of fatigue, 2) by promoting the usage of protective gloves, 3) by using saver machines, motors, or devices; and 4) by general counseling programs on occupational safety. These prevention programs would be cost-effective for prevention budgets per averted injury of between ca. 0.27 and 0.4 million Euro or 0.41 and 0.57 million Euro from an AUVA or overall economy perspective, respectively, that gain about 3.71 to 5.56 QALYs. Preventing a death in this risk group would gain between 15.85 and 23.77 QALYs and would be cost-effective for prevention budgets per averted case of 0.9 and 1.3 million Euro or between 1.2 and 1.6 from an AUVA or total economy angle, respectively. In a next step, the AUVA, together with companies, could investigate in more detail the reasons for and courses of injuries of risk groups suggested by our software in certain companies.

Furthermore, the AUVA could promote better reporting of rehabilitation and prostheses data for injuries within a company. Currently, not all of these costs are connected to a certain injury. In addition, rehabilitation interventions and types of prostheses are not electronically gathered in an exact form. Such organizational strategies would help the AUVA better forecast the future costs of these cost categories.

Currently, a reduction in the AUVA budget for the purpose of subsidizing other social security companies in Austria is being discussed. A reduced AUVA budget would cut the prevention budget of the AUVA resulting in higher costs for occupational injuries which have to be covered not only by the AUVA but also by employers and the economy. Thus, this strategic decision-support system helps the AUVA argue against a cut in its budget by illustrating the potential for cost-effective prevention strategies.

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