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Reference:
Achille J., Ponnet Koen, Reniers Genserik.- Calculation of an adjusted Disproportion Factor (DF⁎) w hich takes the societal acceptability of risks into account
Safety science - ISSN 0925-7535 - 94(2017), p. 171-180
Full text (Publisher's DOI): https://doi.org/10.1016/J.SSCI.2015.12.007
To cite this reference: https://hdl.handle.net/10067/1401500151162165141

Calculation of an adjusted Disproportion Factor (DF*) which takes the societal acceptability of risks into account

Abstract

This paper develops an approach considering parameters related to the societal acceptance of industrial risks, to determine an adjusted Disproportion Factor (DF), whereby the pre-existing calculation model of the Disproportion Factor (DF) developed by Goose (2006) is used as the basis. Our approach will allow companies to have a much more realistic perception and coloured picture of decision-making, where societal acceptability is fully integrated into the calculation process. This way, the decision will not only be more accurate, but also be more defensible. After a literature review, 11 indicators were identified as relevant within the framework of prevention of disasters in companies. Factor analysis confirmed that the 11 indicators represent a societal acceptability of risks (SAR) concept. By using a scoring system we explain how an adjusted DF* can be determined. An illustrative example is also given to show how the model can actually be used. This study thus provides a scoring system that could be used by risk managers in order to include the societal acceptability of risks (SAR) into economic analyses of industrial risks.*

Keywords: *societal acceptability; industrial risks; Disproportion Factor; cost-benefit analysis; safety decision making*

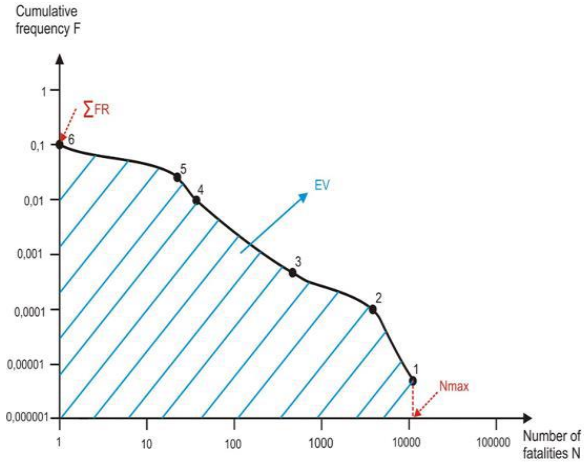
1. Introduction

When talking about how safety concerns are taken into account by stakeholders, economic analyses like cost-benefits analysis (CBA) and cost-effectiveness analysis (CEA) are often used in the decision-making process. What is more, in the UK for example, companies and industrials are even obliged to prove that a risk has been reduced to so-called “so far as is reasonably practicable” (SFAIRP). A possible way of proving SFAIRP is by employing a so-called Disproportion Factor (DF). The model of a disproportion factor (DF) came from the idea of using an intended bias to better support safety over costs. That is why it is sometimes used by risk managers to prove that a further risk reduction is not worth the cost when compared to the benefit in matter of risk reduction and safety management for major accident prevention. This economic model was developed by Goose in 2006. The required input information and calculation method will be briefly described in this paper in order to understand how this model works and can be used.

More particularly, the proportion factor (PF) can be defined as the ratio of the costs to the benefits ($PF = \frac{Costs}{Benefits}$). This ratio is then compared to the numerical value of the estimated disproportion factor (DF) in order to determine whether the risk reduction measure can be qualified as ’grossly disproportionate’ or not. This estimated value is calculated thanks to the use of three numbers which can be extracted from an FN curve (as it is possible to see in Figure 1):

- The sum of the failure rates, written $\sum FR$, and expressed in events per year.
- The expectation value (EV) which is also called Potential Loss of Life (PLL) represents the average number of casualties expected per year. As shown in figure 1, this is the area under the FN curve.
- The maximum number of potential fatalities, written N_{max}, representing the worst case scenario consequences with respect to the number of people killed for a single event.
- A fourth value can be calculated with the ratio of EV to $\sum FR$, representing N_{av} , that is, the average number of fatalities per event, written $N_{av} = \frac{EV}{\sum FR}$.

Figure 1: Illustrative FN curve and input information for the DF calculation



The calculation method gives an order of magnitude for the disproportion factor and therefore it is possible to make comparisons between different scenarios and major historical accidents. The global formula used to calculate the DF is composed of the multiplication of the three ‘How’ factors and the addition of the number 3 (in order to be sure that safety is focussed upon):

$$DF = 'How\ bad' * 'How\ risky' * 'How\ variable' + 3$$

Each ‘How factor’ is estimated individually with a similar formula:

$$'How\ bad' = log_{10}(N_{av})$$
$$'How\ risky' = log_{10}(10^5 * EV)$$
$$'How\ variable' = log_{10}(\frac{N_{max}}{N_{av}})$$

Unfortunately, there are no moral aspects included in the DF model other than the number of fatalities. That is why the idea here is to take “societal acceptance” into account which can be viewed as public consent about management practices. This definition closely comes to the one given by Sandman (2012) using the level of outrage as a proxy of societal (in)acceptance. Societal Acceptability of Risk (SAR) can also be linked to the notion of Social License to Operate (SLO) described by the non-profit organization called Business for Social Responsibility (2003). The idea is to be able to avoid situations with tensions between surrounding communities or employees and other shareholders. Furthermore SAR can be seen as social expectations which, if not met, create oppositions that could delay the production, increase certain costs and even compromise new projects. There are several possible impacts due to local oppositions: reputational damage, share prices decreases, low motivation of employees or even poor attractiveness of new employees. SAR has been studied for decades from different perspectives but remains very disputable because it tries to model and predict human behaviour and response which is a very complex issue involving many fields and disciplines such as for example social sciences, psychology, sociology, safety science and risk analysis.

2. Literature Study

2.1. Risk perception and societal acceptability

In 1978, Fischhoff and colleagues described a psychometric study in which was demonstrated that feelings of dread were the major determiner of public perception and acceptance of risk for a wide range of hazards. A psychometric questionnaire was used in order to correlate nine characteristics of risks resulting in two main factors. The factor “dread risk” included the following items: perceived lack of control, catastrophic potential, inequitable distribution of risks and benefits and, fatal consequences and dreadful. The “unknown risk” factor consisted of the items observability, experts’ and lay people’s knowledge about the risk, delay effect of potential damage (immediacy) and novelty (new-old).

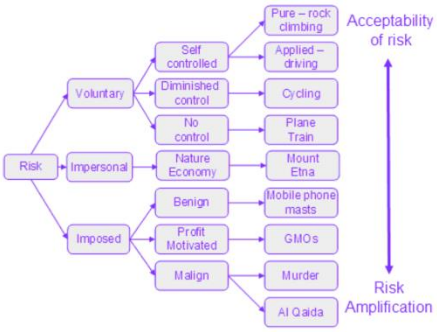
In a study by Huang et al. (2013), the goal was to find correlations between public perception of the chemical industry and its acceptance in matter of risks. Based on a survey administered from 1190 participants, four different factors related to social acceptance were found, each one being subdivided into two sub-factors. The first factor, ‘Knowledge’, consists of a newness factor and a knowledge factor. The second factor, ‘Benefit’, consists of the benefit and immediacy together. Then ‘Effect’ matches with the third factor and is divided between social effect and dread. Finally, ‘Trust’ is the last one, including controllability and trust in governments.

The four factors were then linked with social acceptance through a regression analysis. It is however important to precise that knowledge should be understood from the perspective of citizens’ points of view and the social effect actually implies ’How many citizens are exposed to the risk?’. Moreover, the factor ‘trust in government’ concerns also related policy makers in a broader sense.

In a study by Gurian (2008), the focus was more on how risks are perceived and considered by the general public and society rather than to focus on the industry’s point of view. Based on theoretical explanations, Gurian defined three factors that influence risk perception. The first one is called ‘Dread’ and includes gut level (related to intuition), the emotional reaction due to risk, threat to future generations, control over the risk, equitability and catastrophic potential. The second factor, 'Familiarity', was composed of delayed effects, newness, understood by science or not, and encountered often by the public or not. Finally, the last factor was about the 'number of people exposed to the risk'.

Adams (2009) used the Risk Thermostat model to describe perception of risks and again a new classification of risks is given depending on 3 main factors which are voluntariness, individual control and profit motivated. The acceptability model developed by Adams and resulting from the risk thermostat model is shown in Figure 2.

Figure 2: Acceptability model developed by Adams (2009)

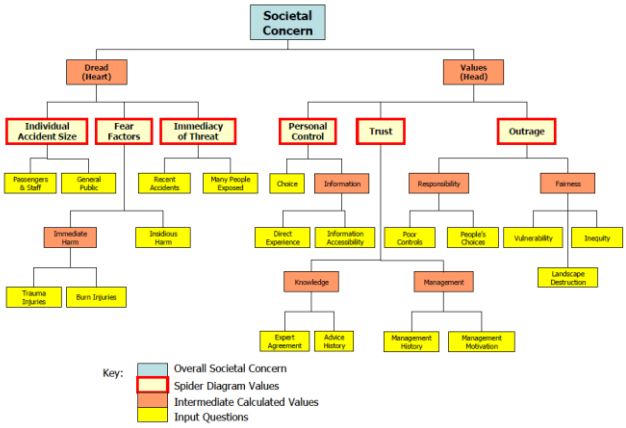


This study is very similar to Gurian (2008), Fischhoff et al. (1978) and Huang et al. (2013) since it focused on the perceived levels of risks to laypeople.

A study of Baker et al. (2004) takes societal concerns into account from a risk managers' point of view. The Baker model can be seen as an adaptation of a previous research study conducted by Mansfield (2003). Mansfield's more complex model describes a variety of societal concerns in the decision-making process. Baker and his colleagues (2004) constructed a systematic framework for the Rail Safety & Standards Board (RSSB) that helped to determine the extent of societal concern in specific cases. They even mention that they believe that a systematic framework is required so that it is completely transparent what factors have been considered in any facilitated evaluation. However, this model is focused on the transport and rail industry and cannot be used directly for industry in general.

Figure 3 represents how the model is structured with the 6 high-level concern factors. As found in several studies, they use spider diagrams to present the results which allow an interesting visual representation of the results.

Figure 3: Structure of the model developed by Baker et al (2004) for the rail industry



In a study by Sandman (2012), the goal was to develop a software that allows a prediction and management solutions to deal with what they call 'outrage' which is closely related to the notion of societal acceptability. Sandman defined risk as the sum of hazard and outrage, with hazard being the standard, well-known, term used by risk managers (Hazard = Magnitude*Probability) and outrage being related to public's perception of risk. The idea is that risk assessors see Risk only as Hazard, for example only with the expected annual mortality, whereas the public sees it as a combination of Hazard and Outrage. Twelve 'outrage items are then given and can be described in this case with two words each time. The first one standing for lower chances of outrage and the second one implying higher chances of outrage: Voluntary vs Coerced, Natural vs Industrial, Familiar vs Exotic, Not memorable vs Memorable, Not dreaded vs Dreaded, Chronic vs Catastrophic, Knowable vs Unknowable, Controlled by us vs Controlled by them, Fair vs Unfair, Morally irrelevant vs Morally relevant, Trusted vs Not trusted, and finally Responsive process vs Unresponsive process.

2.2. Societal acceptability indicators with respect to disaster-related risks

In this section, indicators provided by literature influencing societal acceptability with respect to disaster-related risks are described and a brief comment and description is provided about the approach being elaborated. In fact, the indicators mentioned by literature all play a role when it comes to determining the possible acceptability of a level of risk. They are however not always relevant when the focus should be on disaster-related risks, and from the viewpoint of company safety management. The framework of this work is therefore constrained to the industrial sector making risk assessments for major accidents prevention. That is why only the indicators concerned with societal acceptability related to major accident risks, will be presented, and it will also be explained how these indicators can be organized and grouped together, and finally used in the approach that we elaborate and propose. In fact, the main goal in this part is also to draw parallels between different indicators used in literature which could refer to the same idea or concept and therefore be merged under a same indicator. The eleven indicators are the following:

Indicator n°1 – Trust in governments, experts and company (technical community)
It is a matter of confidence in those responsible for understanding and managing the risks. It is sometimes also seen as 'credibility', meaning that there is a regulation and effective enforcement. In the literature, it is mentioned in studies of Mansfield (2003), Baker (2004), Sandman (2012) and Huang et al. (2013).

Indicator n°2 - Allocation of risks and benefits
Is there a fair distribution of benefits for the risk bearers? It is more or less mentioned in a study of Huang et al. (2013) with a discussion about local economic development. The tricky point here is that an industrial activity might always be seen as more beneficial for the company (in the risk bearers' point of view) and therefore might create a bias in the scoring model. It might also be correlated with profit motivation (Adams, 2009). In the literature, it is also mentioned in studies of Otway (1982), Baker (2004), Sandman (2012) and Huang et al. (2013).

Indicator n°3 – History of bad advice

It concerns the history of the company regarding the given risk and generally if there were recent accidents involving the company itself. It can also be referred as history of bad practices. However, it is possible to wonder whether it is already taken into account with the trust factor or not. In the literature, it is for example mentioned in studies of Mansfield (2003) and Baker (2004).

Indicator n°4 – Common-Dread

It is again a very subjective point and it might be possible to group it with personal experience (or difficulties in conceptualizing the risk exposure). It can be referred as well as fear of harm (Baker, 2004), emotional reaction or gut-level (Gurian, 2008). In the literature, it is mentioned in studies of Fischhoff et al. (1978), Mansfield (2003) and Sandman (2012).

Indicator n°5 – Manmade vs Natural causes

This point is related to whether the accident is due solely to natural causes or if it is a modern technological catastrophe. For example, an accident caused only by hard to predict natural causes may be more accepted than one caused by technical failure. In the literature, it is mentioned in studies of Otway (1982), Mansfield (2003), Baker (2004) and Sandman (2012).

Indicator n°6 – Scientific knowledge

Also referred as uncertainties, it is defined as the experts' knowledge and agreement about the considered risk. In the literature, it is mentioned in studies of Fischhoff et al. (1978), Otway (1982), Mansfield (2003), Baker (2004), Gurian (2008) and Sandman (2012).

Indicator n°7 – Lack of personal experience

Sometimes grouped with personal knowledge, it is also a sensitive and subjective factor. In the literature, it is mentioned in studies of Otway (1982), Mansfield (2003) and Baker (2004).

Indicator n°8 – History of the risk itself

It is related to the history of the hazard itself (for risk bearers), e.g. if there was a recent accident involving the same hazard. It can also be referred as frequency of the hazard. In the literature, it is mentioned in studies of Baker (2004) but also of Sandman (2012), which describes it as accidents that linger in public's mind. According to the latter, it is also closely related to personal experience as well as news, fiction symbols and even signals such as an odour.

Indicator n°9 – Public's knowledge

Also referred as uncertainties to the risk bearers or accessibility to reliable information (and even difficulties in conceptualizing the risk exposure), this point is hard to assess because it is strongly subjective. In the literature, it is mentioned in studies of Fischhoff et al. (1978), Otway (1982), Mansfield (2003), Baker (2004), Sandman (2012) and Huang et al. (2013).

Indicator n°10 – Environmental/Ecological impact

It is difficult to assess how important this point is to people even if now we know that environmental issues raise more concerns than before. In the literature, it is mentioned in studies of Mansfield (2003) and Baker (2004).

Indicator n°11 – Lack of personal control over the hazard/situation

It can be seen as the possibility of avoidance thanks to personal skills for example, or the existence of alternatives for the risk bearers. In the literature, it is mentioned in studies of Fischhoff et al. (1978), Otway (1982), Baker (2004), Adams (2009), Sandman (2012) and Huang et al. (2013).

2.3. Factor analysis and resulting classifications of relevant factors

In order to classify the different indicators, a factor analysis has been conducted and the results led to the development of the scoring system that follows. The purpose of the present study was to examine the factor structure of the Societal Acceptability of Risks (SAR) scale.

2.3.1. *Procedure and participants*

Data were collected via a web-based data collection software programme, Survey Monkey. In total, some 800 persons received a personal e-mail asking them to participate in an online cross-sectional study on risk acceptability. The participants were randomly chosen students and staff members of the Faculty of Industrial Entrepreneurship, the Faculty of Applied Economic Sciences and the Faculty of Chemistry of the author's institution. The link to the questionnaire was active during 14 days in July and August 2015. No reminder email was sent. To protect privacy and confidentiality, no personal details were administered from the participants.

The survey consisted of 11 items on the societal acceptability of risks. As mentioned above, the items were created after a literature study on the subject of risk perception and a first sorting of relevant factors depending on the framework of industrial risks management [e.g. voluntariness exposure not relevant in the sense that it is an occupational hazard]. In total, 112 participants filled out the questionnaire, resulting in a response rate (i.e. 14%) that is slightly lower than other online surveys among college students (e.g. Ponnet et al., 2015). This however can be attributed to the period of administration, i.e. the holiday period. One participant was excluded because of failure to complete the questionnaire adequately. The average age of the remaining 111 participants was 30.36 years old (*SD* =13.42), with 63% males (*n* = 70). With regard to employment, 36.9% (*n* = 41) of the participants were employed, and 63.1% (*n* = 70) were students or had just finished their studies.

2.3.2. *Results*

Item means and standard deviations are presented in Table 1. Standard deviations are relatively consistent across the items. Internal consistency of the eleven item set was acceptable, with Cronbach alpha = .69.

Table 1: Descriptive statistics of the items

		M	*SD*	*range*
Item 1.	The trust in company's safety management, and especially for the considered major accident hazard	4.49	.70	1 - 5
Item 2.	The fact that risks and benefits are not fairly distributed among risks bearers	3.75	1.01	1 - 5
Item 3.	The fact that the company has faced major industrial accidents before	4.07	1.07	1 - 5
Item 4.	The fact that risk bearers have great fear of the considered hazard	3.88	1.08	1 - 5
Item 5.	The fact that the major accident hazard might be caused solely by human-related actions (as opposed to natural causes)	3.72	1.11	1 - 5
Item 6.	The fact that experts do not necessarily agree on how the risk should be managed, because of scientific uncertainties concerning the considered hazard	3.36	1.23	1 - 5
Item 7.	The fact that the risk bearers do not have personal past experience of the considered risk	3.50	1.09	1 - 5
Item 8.	The fact that a major accident involving the same certain type of hazard has occurred in the past few years somewhere in the world	4.05	1.13	1 - 5
Item 9.	The fact that people bearing the risk (that is, those persons exposed to the major accident hazard) do not have knowledge about the specific risk	4.18	1.04	1 - 5
Item 10.	The fact that the hazard has an environmental impact	4.05	1.08	1 - 5
Item 11.	The fact that the risk bearers, once the major accident occurs, do not have control over the situation at hand, or it is extremely difficult to get control over it	4.02	1.06	1 - 5

First, the SAR was subjected to an exploratory factor analyses (principal components with varimax rotation) conducted with SPSS Statistics 22 to suggest a possible factor structure for the pool of eleven items. Consistent with other questionnaire validation studies (Fahlman et al., 2013; Suldo et al., 2009), an item was considered salient for a given factor if it loaded on that factor at .40 or higher and .30 or lower on other factors. The scree plot and eigenvalues suggested a four-factor solution that accounted for 56.22% of the variance. All eigenvalues exceeded 1.0. The first factor consisted of 4 items and explained 24.73% of variance, the second and third factor each consisted of 3 items, with 11.78% and 10.10% explained variance, and the fourth factor consisted of only 1 item that explained 9.61% of the variance. As shown in Table 2, all of the items loaded good (i.e. > .40) on only one of the four factors.

Factor I (4 items) consists of items related to the awareness of company about the risk and fairness of dealing with it. Factor II (3 items) consists of items related to trust in risk bearers. Factor III (3 items) consists of items related to the characteristics of the major hazard and its consequences and factor IV refers to trust in safety management.

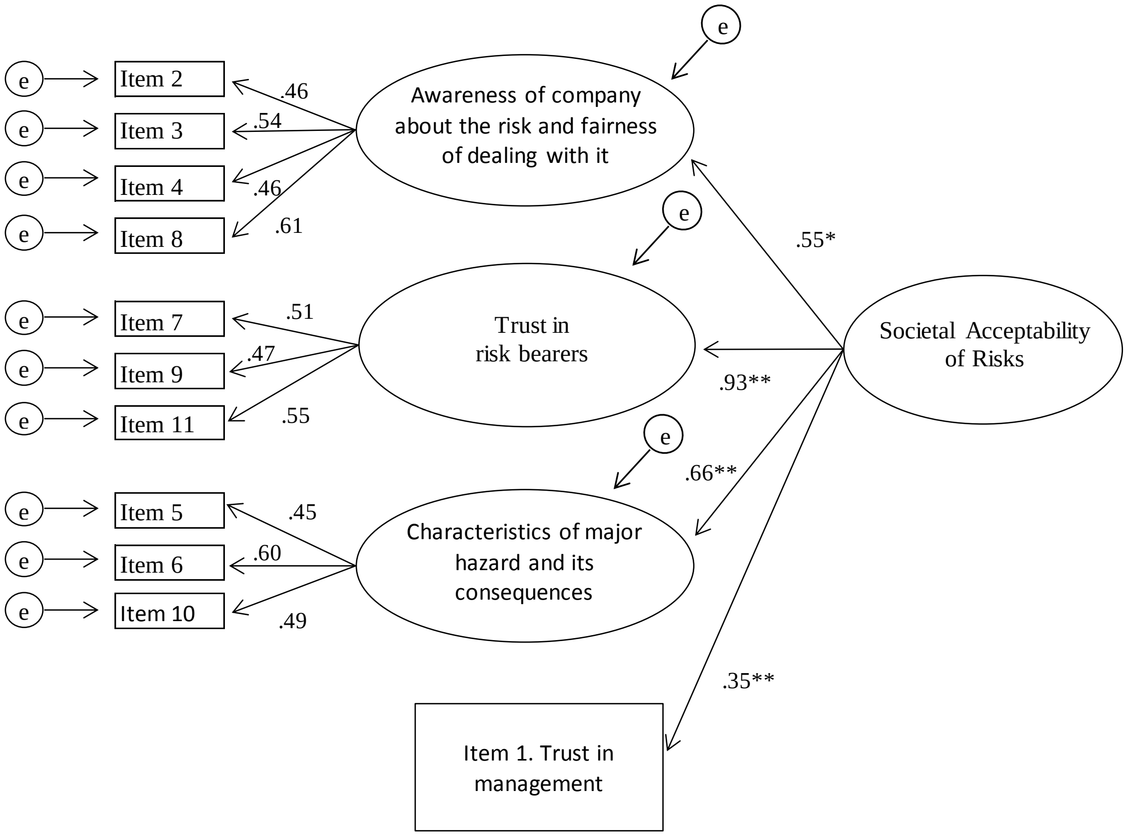
Table 2: Exploratory Factor analysis.

	Factors			
	I	II	III	IV
Item 2.	**.41**	.29	.14	.03
Item 3.	**.57**	.06	-.01	.21
Item 4.	**.42**	.19	.14	-.10
Item 8.	**.61**	.18	.04	.03
Item 7.	.15	**.44**	.20	-.02
Item 9.	.13	**.41**	.06	.18
Item 11.	.17	**.58**	.09	.05
Item 5.	-.01	.12	**.66**	-.11
Item 6.	.08	.27	**.44**	.16
Item 10.	.30	.05	**.41**	.16
Item 1.	.05	.10	.03	**.59**
% of variance	24.73	11.78	10.10	9.61

Next, to verify the four-factor structure found with exploratory factor analysis, a confirmatory factor analysis was conducted on the items using Mplus 6 with maximum likelihood estimation. Because the four factors were intended to represent specific correlated aspects of the societal acceptability of risks, a model with a single second-order factor was estimated. Since Factor IV consisted of a single item (item 1), we compared the fit of a second-order factor model with four fist-order factors (Factor I to IV) with the fit of a second-order factor model with three first-order factors (Factor I to III). Model fit was evaluated with the chi-square test (χ^2), comparative fit index (CFI), the Standardized Root Mean Square Residual (SRMR) and the Root Mean Square Error of Approximation (RMSEA) along with its 90% confidence interval. The CFI ranges from 0 to 1.00, with a cut-off of .95 or higher indicating that the model provides a good fit and .90 indicating that the model provides an adequate fit (Hu & Bentler, 1999). An SRMR value below 0.08 indicates a good model fit (Hu & Bentler, 1999). RMSEA values below .05 indicate a good model fit, and values between .06 and .08 indicate an adequate fit (Brown, 2006; Ponnet, 2014).

The fit of the second-order model with four first-order factors was good, with $\chi^2(42) = 31.84$, $p = .87$, CFI = 1.0, SRMR = .06 and RMSEA = .00 (CI: .00 - .03). The results of a χ^2 difference test indicate that omitting Factor IV (item 11) did not increase the fit significantly ($\chi^2(10) = 9.72$ $p = .46$). Therefore, the four first-order factors model was preferred above the three first-order factors model.

Figure 4: Second order factor structure of the Societal Acceptability of Risks



Note.
Model fit: χ2(42) = 31.84, *p* = .872, CFI = 1.0, SRMR = .06, RMSEA = .00 (CI: .00 - .03)
***p* <. 001

As shown in Figure 4, the first-order standardized loadings were all strong, ranging from .46 to .61. With respect to the second-order loadings, the “trust in risk bearers” factor had the strongest relationship with the second-order factor (.93), followed by “characteristics of the major hazard and its consequences” factor (.66), “awareness of company about the risk and fairness of its management” factor (.55), and the “trust in management” (.35). These results indicate that the total score of the SAR is meaningful.

The factors presented as relevant have therefore been sorted and included into a scoring system explained in what follows. The classification of each indicator into the main factors (F_I, F_{II}, F_{III} and F_{IV}) has been done depending on their order of consistency in the factor analysis but the same weight in the scoring system has been applied in the end due to small differences between them.

3. Scoring system development

3.1. Level of societal concern

The model developed in this section is a scoring system that can be directly filled in by safety management, for example by board members of a safety committee in the perspective of assessing societal concerns that might raise before or after an accident occurred, and that may thus be important while deciding on safety investments. The idea is therefore to try to picture how workers in a company or outsiders view the safety management set up in their workplace and what kind of concerns they could have. There are indeed cases where the costs due to a strong public reaction were really high. This system therefore identifies, from the perspective of the company managing the hazard, the potential factors influencing this type of situations.

The different factors as listed in the previous section, can be grouped into subcategories. Ideally, each subcategory tackles a ‘key idea’ of societal acceptability of risks. Since the standard calculation of the DF as proposed by Goose (2006) already takes into account the maximum number of casualties (N_{max}) and the average number of fatalities per year (EV) and per event (N_{av}), these factors (which is often described as severity of consequences) should not be considered another time in the model that is being elaborated. As already explained, the goal of the model is to offer an approach about how to include moral aspects into the DF, taking societal acceptance of major hazards into account for the industrial sector in general. It therefore incorporates each relevant factor into a scoring system that gives the global level of concern as an output. Depending on the level of societal concern, the DF is then modified accordingly.

Furthermore, the developed model needs to be designed with the persistent idea that it is always possible to use a neutral score for each question. This implies that if one scores between 0 and 4, e.g. 2, this should indicate some kind of neutrality. This way, it is possible for the user of the scoring system to ‘skip a question’, for example if the indicator seems not appropriate or if it does not fit the considered case.

Table 3: Overview of the factors and indicators.

Names of the factors and indicators	**Range of the scores for calculating the DF***
1. Awareness of company about risk and fairness of its management (16 points max)	
Indicator 1. Individual control over the hazard/situation The indicator questions whether there were recent accidents involving the same hazard? (And is it relevant, meaning that people still recall this event?) It can be seen also as previous accidents drawing a lot of media attention or strong protests.	0 = hardly any records of accidents of the same type 2 = neutral score 4 = many records of accidents of the same type
Indicator 2. History of bad advice The indicator is a reflection of the fact whether the company has faced a large scale industrial accident before, which can be assumed to be still in the risk bearers' memory?	0 = excellent safety records for the company 2 = neutral score 4 = poor safety records for the company
Indicator 3. Fair allocation of risks and benefits The indicator wants to determine whether the risks and benefits are fairly distributed over the risk bearers and the risk beneficiaries. In fact, the aim is to avoid cases of moral hazards when one person is willing to maintain a risky situation because he or she does not bear the consequences and only has the benefits	0 = a fair distribution of risks and benefits 2 = neutral score 4 = an unfair distribution of risks and benefits
Indicator 4. Common-Dread The indicator questions whether the risk bearers are able to reason in a rational way when facing the hazard/situation. Does the possibility exist that risk bearers have great dread and they would not have a proper reaction? The idea here is to determine the level of fear of harm or the level of emotional 'gut reaction'. It can be seen also as a possibility of dramatization of the risk by the public	0 = a hazard which is not so scary 2 = neutral score 4 = a great dread associated with the considered hazard
2.Trust in risk bearers (12 points max)	
Indicator 1. Individual control over the hazard/situation The indicator tries to capture the level of personal control over the situation for the person exposed to the risk. It can also be seen as the availability of alternatives when facing the hazard. With this factor, the possible response skills of the risk bearers can be evaluated	0 = a total control for the individual 2 = neutral score 4 = no control at all for the individual
Indicator 2. Lack of personal experience The indicator verifies whether there is a lack of personal experience of risk bearers for the considered risk? In fact, if risk bearers have personal experience with the risk/situation, the risk is more likely to be accepted	0 = strong experience for the individual 2 = neutral score 4 = no experience at all for the individual
Indicator 3. Uncertainties: public's point of view The indicator can be seen as the public's knowledge of the considered risk, that is, how much does the public at large, or more specifically the risk bearers, know about the hazard? Is it well-known by the public? Do people understand easily this risk? It could also be seen as the accessibility to reliable information	0 = easily known by the public 2 = neutral score 4 = the existence of great uncertainties or hard to understand
3. Characteristics of the major hazard and its consequences (12 points max)	
Indicator 1. Uncertainties: science point of view The indicator can be seen as the experts' knowledge and agreement concerning the studied hazard. How much does science know about the risk? Is it well known by the technical community? Do experts agree on how to manage the risk	0 = perfectly known by the technical community 2 = neutral score 4 = the existence of large uncertainties or no agreement at all among scientists
Indicator 2. Environmental impact	0 = no environmental impact

The indicator assesses whether the hazard could have a (major) environmental impact or not. For example, a chemical leak into a river or a radioactive fallout could have a major impact upon perception of the risk.	2 = neutral score 4 = tremendous environmental impact
Indicator 3. Manmade vs Natural causes The indicator wants to determine whether the possible accident could be caused by human mistakes or by natural causes. A human failure (score ‘2’) can be for instance a miscalculation of the resistance of a physical barrier or a mismanagement of the risk. As an example of the neutral score, a plane crash due to a storm can be given	0 = purely natural causes 2 = neutral score 4 = purely human and/or technical causes
4. Trust in company’s safety management (4 points max)	
The factor, represented by one indicator, indicates to what extent is believed that the people exposed to the risk (or the citizens most likely to criticize company policies) trust company’s risk management abilities? The main idea of this factor is to take into account the perception of risk bearers about company’s safety management.	0 = a complete trust in management 2 = neutral score 4 = a complete mistrust in management practices

3.2. Effective use of the scoring system – Calculation of DF*

Different factors can determine whether some societal concerns might arise or not from a situation. A value needs to be assigned to each indicator, so that a value is determined per factor, eventually providing a corresponding weight factor in the equation to calculate the DF*.

However, suitable ranges of values need to be carefully chosen so that the original DF does not change too much. In fact, the idea is to have slight modifications of the value calculated with the economic model developed by Goose (2006). The estimated level of societal concern (low, neutral or high) should just be an indication for the value of the weight factors applied to the DF in order to give the modified DF*. This specific point has been verified by a sensitivity analysis described in the next section.

In the following model, the user should bear in mind that the advised range of values given by Goose (2006) for the DF remains between 3 and 30 ($DF \in]3;30]$). It is possible to imagine a case where high societal concerns could raise the DF over 30 but that should only concern very specific cases.

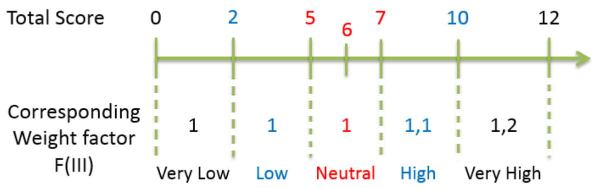
An Excel document can be created for this purpose, containing all needed calculations on a unique spreadsheet and therefore allowing a direct use of the scoring system. The factor table summarizing the layout for each factor and indicator in the Excel document is presented in Figure 5. It is important to precise at this point that the model explained in what follows should be considered only as a guidance tool. It should therefore be interpreted as a suggestion and not like the only possible way to do it.

Figure 5: Layout of the factors in the Excel document

Main factors	Indicators	Scores	Score Guidance
F(I) - 4 items - Awareness of company about the risk and fairness of its management (16 points max)	I.1 - History of the risk itself for the risk bearers		Between 0 and 4
	I.2 - History of bad advice		Between 0 and 4
	I.3 - Fair allocation of risks and benefits		Between 0 and 4
	I.4 - Common-Dread		Between 0 and 4
Total for Factor I			
F(II) - 3 items – Trust in risk bearers (12 points max)	II.1 - Individual control over the hazard/situation		Between 0 and 4
	II.2 - Lack of personal experience		Between 0 and 4
	II.3 - Uncertainties: public's point of view		Between 0 and 4
Total for Factor II			
F(III) - 3 items - characteristics of the major hazard and its consequences (12 points max)	III.1 - Uncertainties: science point of view		Between 0 and 4
	III.2 - Environmental impact		Between 0 and 4
	III.3 - Manmade vs Natural causes		Between 0 and 4
Total for factor III			
F(IV) - 1 item - Trust in company (4 points max)	IV - Trust in company		Between 0 and 4

A separate spreadsheet may be created with the weight factors that should be applied depending on the total score for each main factor. An example of how the weight factors are chosen is given in Figure 6.

Figure 6: Example of factor value F_{III} and its corresponding weight factor WF_{III}



It is relevant to precise that a choice needs to be made concerning the possible negative impact of this kind of assessment. It has been supposed that social impacts are rarely in favour of a company,

especially in industry. That is why it is impossible to reduce in this model the value of the DF with a weight factor lower than 1.
The final step is then to multiply the initial value of the DF with the four weight factors (WF_i) as described in the following formula:

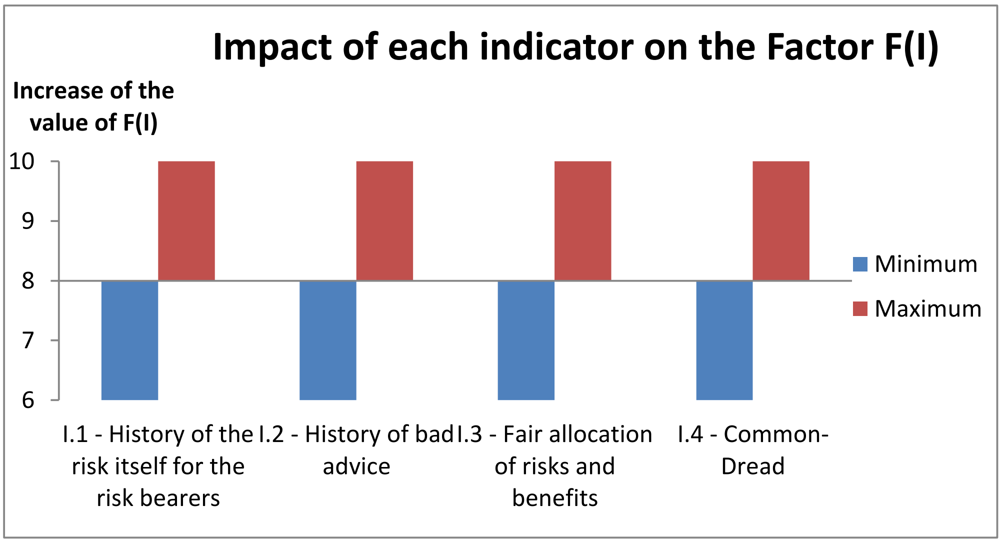
$$DF^* = DF.WF_I.WF_{II}.WF_{III}.WF_{IV}$$

3.3. Sensitivity analysis

A sensitivity analysis has been performed on the model to study the maximum change in the value of the DF after modification. In this part, the model structure is therefore tested and the changes in the results presented in percentage of modification in relation to the neutral value. The purpose of this sensitivity study is to quantify the impact on the global output, which is the final value DF*, so that the decision maker has an idea of the impact of taking societal concerns into consideration in the calculation of the disproportion factor.

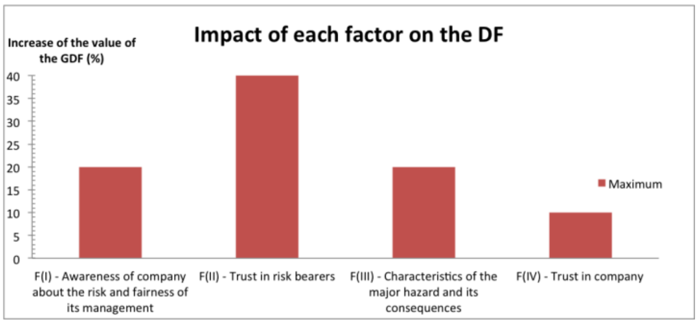
In a first part, the impact of each indicator on each main factor has been studied as can be seen in Figure 7. The fact that each indicator has the same weight implies the same impact on the value of the main factor.

Figure 7: Example of a sensitivity analysis of the indicators on the value of the factor



The impact on the DF is then studied for each main factor F_i as shown in Figure 8. It is possible to see that the maximum change of 40% is with F_{II}. It is logic in the sense that this factor has been presented earlier as the most important to people thanks to the results of the factor analysis.

Figure 8: Sensitivity analysis of each main factor F_i on the global value of the DF



It is important to precise that the sensitivity analysis has been performed on a separate spreadsheet of the same Excel document as mentioned earlier. However, the method remains limited in the way that it does not consider several changes at the same time. It means that a simultaneous error in evaluating two factors would not be taken into account. This is the reason for carrying out a multiway sensitivity analysis: the study of the impact caused by the maximisation of the four main factors reveals that the maximum impact on the DF would be an increase of around 222 % of its value (the DF would be multiplied by 2,22). It would happen only on extreme cases where societal concerns would be abnormally high on each and every factor and indicator.

3.4. Illustrative example

In this part, we use an example where the DF is already calculated and we observe how the scoring system can be used in practice. The goal is to see whether the model and the results are logic and relevant.

The starting point here is to use one of the examples developed by Goose (2006) in his paper which is first described in the HSE research report written by Quinn et al. (2004). The example concerns a chlorine installation consisting of road tanker deliveries of 2×80 ton vessels via pipework and supply to a user location. Goose (2006) calculated the DF value for the plant to be 12.2. However, since it is an illustrative example, the authors did not make assumptions concerning the characteristics of the organization in charge of managing this hazard, which is an important criterion for the assessment of the DF* using our proposed scoring system. That is why in the following example, an existing organisation A (remark that we call it A due to confidentiality reasons) was chosen by us in order to have a more specific and concrete case to work on. A is a well-known chemical concern that has a lot of experience in dealing with chemicals and especially chlorine.

Estimation of the level of societal concern

In this part, the different steps of the scoring system will be briefly detailed and comments will be provided in order to be clear concerning the approach of our proposed model. Disagreements can rise from the scores attributed to the indicators. In fact, several results coming from different people would allow to assess more precisely the repeatability and the robustness of this system.

F_I - Awareness of company about the risk and fairness of its management

I.1: A score of 4 has been given because researches have shown that there has been a lot of accidents involving chlorine as it is possible to see in this extract from an article on the Internet: “Over the past 10 years, chlorine has been involved in hundreds of accidents nationwide, injuring thousands of workers and townspeople, and killing some, according to federal databases.”[1]

I.2: A score of 1 has been given because after some researches about their accidents history, except for a recent explosion in one of their chemical plant, organization A has relatively good safety records.

I.3: A score of 3 has been given because the chemical industry is mostly beneficial for the company that sells and uses chemicals but the workers still receive a wage for their work.

I.4: A score of 4 has been given because people still have a strong negative image of chemicals and they may have a great dread when facing this kind of event.

That gives a total score of 12, giving a corresponding weight factor WF_I=1,1 (High-risk area).

F_{II} – Trust in risk bearers

II.1: A score of 4 has been given because once the hazard occurred, workers do not have control over the exposure.

[1] http://www.scientificamerican.com/article/chlorine-accidents-take-big-human-toll/

II.2: A score of 3 has been given because even if the workers are specialized in chemical transport for example, they do not have necessarily experienced a real chemical exposure before.
II.3: A score of 3 has been given because exposed workers do not necessarily have a scientific background. They probably have a specific training for that kind of risk but many uncertainties might remain.

That gives a total score of 10, giving a corresponding weight factor WF_{II}=1,2 (High-risk area).

F_{III} - characteristics of the major hazard and its consequences
III.1: A score of 0 has been given because storing and managing chemicals is a well-known subject. It is therefore possible to suppose that they are used to deal with this kind of hazard for a long time.
III.2: a score of 3 has been given because it would definitely have an environmental impact, but not necessarily a tremendous one.
III.3: A score of 4 has been given because the hazard is entirely manmade.

That gives a total score of 7, giving a corresponding weight factor WF_{III}=1 (neutral area).

F_{IV} – Trust in company
The company can be considered as fully trusted so the score here is 0. That gives a corresponding weight factor WF_{IV}=1 (very low-risk area)

Finally, after multiplying everything together, a modified DF* of 16,1 is found, instead of the original DF of 12.2. The result seems logic and not too impactful. It is reasonable since the chemical industry keeps having a negative image to the public's point of view.

3.5. Discussion of the suggested scoring system

This study provides a scoring system that could be used by risk managers in order to include the societal acceptability of risks (SAR) into economic analyses of industrial risks. Remark that companies may also consider to obtain the scores via panels of experts instead of using the scores obtained from students, as was done in this paper in order to develop the methodology.

Advantages of this scoring system include the fact that it is rather user-friendly. Moreover it is quite easy to understand and to picture each of the parameters included in the model, and especially how it works as a whole. It is also flexible in the sense that it can be adapted to different types of situations. Specific parameters can even be chosen as neutral so that they have no impact on the final outcome. Finally, the scoring system is complete in the sense that all the indicators, known as influential for the societal acceptability of risks and relevant within the framework of the prevention of major industrial accidents, have been included and weighted differently depending on their importance.

Disadvantages of this model, as it is for now, include the subjectivity introduced by the fact that users are free to change some of the parameters and to apply different weight factors depending on the desired sensitivity and final impact on the DF. This might lead to cases where results would be too impactful on the value of the DF as mentioned earlier in the multiway sensitivity analysis. Another item of concern is that this model still needs risk managers ready to take the leap and actually begin using it and including it into economic analyses of their organisations' risks.

5. Conclusions

The developed scoring system allows the user to assess the level of societal concerns by identifying situations where public outrage could burst. It provides guidance as well about the main factors influencing societal acceptability along with a way to include it into the previously developed DF model thanks to weight factors. In fact, eleven indicators have been identified, explained and grouped into four main factors.

As leads for further adjustments, it is possible to imagine for example the development of actual software with an interface that would make it even more user-friendly and with a broad database that allows access to information and good descriptions of the terms or the context. It could provide details about every parameter but also on specific cases and give examples on how to solve some issues related to this topic (e.g. trust improved with better risk communication or knowledge of workers increased with awareness campaigns).

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