# A Cost-Benefit Approach to Thermo-Processing Equipment Safety Regulation Analysis

**Motshumi Joseph Diphare, Hannelie Nel and Jan-Harm C. Pretorius**
Postgraduate School of Engineering Management
University of Johannesburg
Johannesburg, Republic of South Africa
dipharej@gmail.com, hannelien@uj.ac.za, jhcpretorius@uj.ac.za

## Abstract

Safety management of industrial fuel-fired thermo-processing equipment is important to protect workers, infrastructure and the environment. Potential risks include fire and explosions which can be catastrophic if not managed. Various regulatory agencies across the globe have introduced safety regulation such as NFPA 86, EN 746 and SANS 329 to enforce combustion safety requirements. Like other regulations, these regulations are also experiencing resistance by firms. The main reason of resistance is the unjustifiable compliance costs. The aim of this study is to develop a customized model which can be applied to analyse the cost and benefits of fuel-fired thermo processing equipment safety regulations. The model consists of three components namely, process simulation, financial modelling and cost benefit analysis. Process simulation is used to observe the performance of the compliant and non-compliant system. A financial model is used to observe the effect of process alterations on the cash flow of the project over a period. Once all costs and benefits are projected a cost-benefit analysis can be performed to determine the net present value (NPV) of the project. If NPV > 0, it proves that safety regulation has financial benefit, and if NPV < 0, the project must be rejected. When comparing different alternatives such as project A and B, if NPV(A) > NPV(B), project A must be chosen and vice versa.

## Keywords
Cost-Benefit Analysis, Safety, Simulation, Regulation and Net Present Value.

## 1. Introduction

Regulations, also referred to as administrative laws, are primary mechanisms by which many governments implement and enforce an objective conduct by individuals and mostly organizations (Dudley and Brito 2012). Blind (2012) defined regulation as the implementation and enforcement of rules by public authorities and governmental institutions to influence the market behaviour and private organizations' activities in the economy. Regulations are also used to safeguard the citizenry from engaging in hazardous activities. In this instance the regulating body has the responsibility to spread awareness and educate the public. Failure to comply with these regulations, affected parties may face from minimum to hefty penalties or even sanctions depending on the seriousness of the transgression. The level of punishment also differs from country to country and the sector in which they are operating.

Regulations are very diverse and have a variety of objectives. These can include forcing corporations to take note of certain prices, to supply certain products, to ensure products meet the specified quality standard, to apply specific technology in the production process or to exercise minimum safety in the work place. Due to the nature of industrial activities, potential risks are often managed by safety standards to guarantee the protection of workers, infrastructure and the environment. These safety regulation standards provide the basis in which how systems and processes should be managed and operated.

Safety standards often offer general direction and guidance based on the consensus work of experts but does not offer distinct solutions for a specific process or safety concern. Safety standards may be performance based or of prescriptive nature (Stavrianidis 2001). Stavrianidis (2001) further reported that safety standards are developed by input from professional associations, industry, government agencies, international associations and companies. Companies must always be adequately consulted to prevent resistance when the standard becomes law.

Hale et al. (2015) reported that safety regulations exist to influence behavior by specifying what the behavior should be or should achieve and applying some form of motivation to encourage it. That motivation may be complex, including some or all of the following: to do a good job, to conform to social expectations and pressures, to comply with the law, or to escape castigation. Johnson (2014) explained that safety regulations are either process or performance based. Performance based safety regulations mainly focus on quantifiable results from a production process or service. Most government agencies encourage organizations to monitor and manage their safety with minimal if not at all formal regulatory intervention. Organization must be initiative and conduct process audits and inspection to identify potential desecrations. Regulators can also set performance standards, without stating how these requirements are to be met. They can ban the use of a certain chemical without providing an alternative. Therefore, it is the responsibility of the manufacturer to find an alternative in order to comply.

On the other hand, process-based regulations concentrate on whether organizations apply techniques that are adequately safe (Johnson 2014). Processes that fail to meet the minimum requirements can lead to even criminal prosecution. Process based regulations normally specify comprehensive measures to be followed to comply with certain standards. However, authorities are reluctant to give alternative recommendations as it is believed this is transfer of responsibility from firms to authorities (Dahle et al. 2012)

Developing countries are facing growing pressures to enhance their production processes in order to ensure protection of the environment and working conditions of employees (Baski and Bose 2016). This pressure is increasing due to global shift in climate change negotiations and safety consciousness among countries. As a result, more states are responding to this with stringent environmental and safety standards.

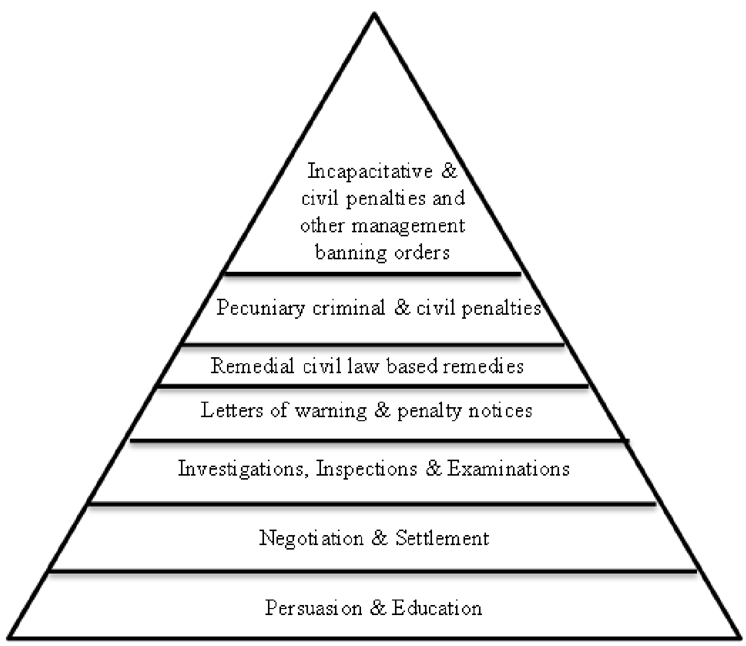


Figure 1. An enforcement pyramid (Johnstone 2004)

Figure 1 shows the hierarchy of enforcing regulations. Johnstone (2004) expressed a view that society or organizations must firstly be educated and persuaded about various regulations before harsher measures can be taken against offenders. The hierarchy shows further steps that can be taken before the worst case can be reached such as criminal charges, civil penalties and banning orders. The shutting down of organizations should be the last resort as this can have adverse consequences on workers, the economy and society in general. According to Windapo (2012), compliance is a practice of adhering to applicable rules, regulations and standards. Safety compliance involves adhering to safety procedures and carrying out work in a safe manner. Kvalheim and Dahl (2016) reported that safety violations are an important factor in accidents and also a frequent finding in investigations and analyses across various sectors of manufacturing. Walker et al. (2012) also reported that one of the most common casual factors that cause fatal incidents and high potential events is violations of safety procedures and guidelines. Research conducted by Hopkins (2008) at the Texas City refinery explosion in 2005, and Hayes (2012) at the Montana explosion all ascertain that lack of compliance with rules and procedures were a major contributing factor in these incidents.

Safety compliance is commonly related with extensive knowledge on effective management practices. Previous research that focused on safety knowledge and safety training found that there is a positive relationship between safety competence and safety compliance (Flin et al. 2000). Kwon and Kim (2013) also found a direct relationship between the level of safety knowledge and safety compliance. Studies by Lu and Yang (2010) also discovered that there is positive relationship between safety training and safety compliance. Flin et al. (2000) also found that having a safety system in place has a positive influence on safety compliance by workers. Other factors which contributed positively to safety compliance included willingness of managers, competence of workers and supervision. Work pressure was found to contribute negatively. Arewa and Farrell (2012) reported that most organizations are less likely to comply with safety regulations due to the perception that compliance with these regulations will not improve their financial performance. Kvalheim and Dahl (2016) further reported that the attention of researchers needs to focus more on conditions that promote safety compliance instead of simply identifying violation provoking conditions.

### 1.1 Objectives (11 font)

The aim of this study was to develop a cost-benefit model to assess the cost and benefits of complying with combustion safety regulation.

## 2. Literature Review

### 2.1 Regulatory Challenges in the Thermo-Processing Industry

Many countries have been reporting to be battling with complains of the burden imposed by laws and regulations on industry, particularly where those regulation are of a prescriptive nature (Hale et al. 2015). Dudley et al. (2010) reported that regulatory burden seems to be increasing under every new political administration. This is as a result of evolving technology and eroding of process plants which potentially pose safety risks. In normal practice, when regulatory agencies issue a new regulation, companies spend time investigating whether it applies to them and whether they comply. These investigations take a lot of time and energy of managers and employees who must device and implement the assessments. As a result, human resources are then diverted from other production activities to these assessments.

The other predicament reported by Hale et al. (2015) is that compliance cost may put smaller companies at a competitive disadvantage and discourage entry into markets. Larger firms normally manage to absorb the cost of regulation more easily than smaller ones. Crain and Crain (2010) mentioned that compliance with detailed, prescriptive regulations may build a reactive compliance culture, which stifles innovation in developing new products, processes, and risk control measures. Further concerns include the high compliance costs which can lead to companies questioning the technical justification of some regulations. Another problem is that regulators often respond more slowly than companies to changing market conditions and locking industry into outdated production methods (Hale et al. 2015). Other cost may come from the burden of administration and reporting to regulatory bodies. These costs can reduce competition and increase prices of products and services.

Loosemore and Andonakis (2007) mentions that detailed regulations are hard to understand because of their legalistic phrasing and complexity, and it is often difficult to determine whether a particular rule applies in a given situation. Majumdar and Marcus (2000) showed that detailed rules imposed from the outside discourage companies from conducting their own risk analysis by using their own expertise in their technology and organization to advise best ways to control risk. Fairman and Yapp (2005) reported that most small companies lose their sense of owning and managing the inherent risk in their business. These small companies tend to wait until an inspector visits their premises and then ask them what should be done to comply.
The thermo-processing industry constantly faces the risk of explosions and fires which are associated with fuel fired equipment such as boilers, furnaces, ovens and dryers. A critical time is during startup or shutdown when the

equipment is in transition (Manahan 2012). Explosions are caused by an accumulated combustible mixture is ignited within a confined space or chamber such as an oven or furnace. An explosion can be catastrophic and result in damage to property, loss of life and production. All fuel fired equipment must be fitted some form of combustion safety system to reduce the risk of explosions or fires.

For this reason, it has become a global practice for governmental agencies to introduce safety standards to protect the citizenry, infrastructure and the environment. The most common and popular combustion safety standards are the EN 746 and NFPA 86 which were introduced by Europe and USA respectively. Recently, RSA has introduced its own standard which is SANS 329. SANS 329 is derived from the two above mentioned European and American standards. These standards specify the minimum requirements for the design, manufacturing, installation, testing, operation and maintenance for industrial combustion systems that suppliers and end-users need to follow.

Like any other regulation, combustion safety standards are no exception when it comes to resistance by industrial firms. The reason of the resistance is mostly the high amount of capital investment required and claims that their plants are safe and have been operating incident free for years. The other reason that affects the steel making industry specifically is the current unfavourable economy conditions climate. Liu et al. (2016) confirmed this claim by reporting that big consumers of natural gas such as steel making and mineral industries are facing oversupply and falling commodity prices. As a result, such key thermo-processing industries are focusing their efforts on reducing production costs rather than spending.

Despite all the challenges that governments face globally, safety regulation is still an important tool to protect the ecosystem and to hold firms accountable. Without them workers are exposed to risk on daily basis by employers. Dahl et al. (2013) concluded his studies that safety regulation have benefits in excess of their cost, however, more initiative by governments and regulatory bodies is required to prove this to industries.
Therefore, the biggest task for regulatory agencies is to prove, educate and convince firms that combustion safety regulations are introduced for their own benefit. An effective way of doing this is assessing the cost and benefits of these safety standards. Hopkins (2015) shared the same view that any governmental agency advocating new regulation must pass the cost-benefit analysis or alternatively show why strict cost-benefit analysis is not applicable to justify the regulation. It is for this reason that the aim of this study is to develop a cost-benefit model to assess the cost and benefits of complying with combustion safety regulation.

### 2.2 Cost-Benefit Analysis

CBA is a process of identifying, measuring and comparing the benefits and costs of an investment project or program (Campbell and Brown 2003). A program is normally a series of projects undertaken over a period of time with a particular objective in view. Hanley (2013) simplified the definition of CBA as a technique developed by economists for judging the net benefit or cost of a project or policy. The costs generally include capital expenditure at the beginning of a project and later operational expenses. The benefits can be quantitatively or of monetary value while some can be qualitatively depending on the nature of the project to be undertaken. Livemore et al. (2013) reported that growing environmental; health and life threats from industrialization have increased demand for stringent environmental policies around the globe, bringing the need for a systematic tool regulatory analysis.

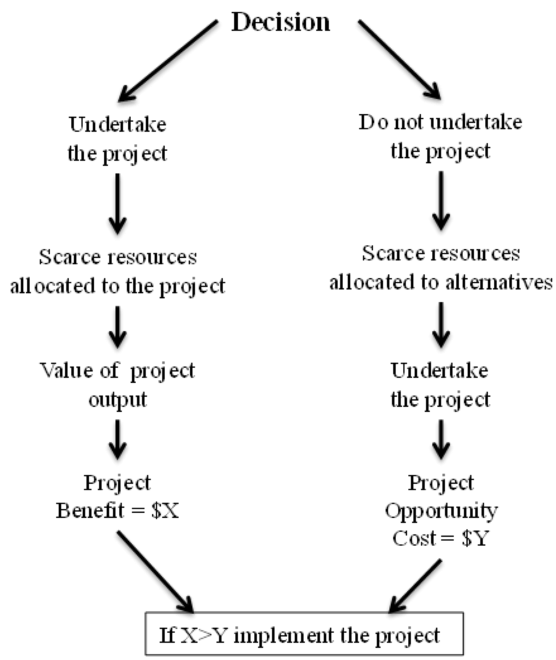


Figure 2. Approach to CBA (Campbell and Brown 2003)

Figure 2 illustrate the typical procedure followed when conducting a CBA. Normally when an investment decision has to be made, it is always necessary to weigh possible projects according to their value or priority. The process compares two alternatives and makes a determination once all benefits and costs are accounted for. If the benefits are higher than the costs, then the project can be implemented. In a case of comparing different projects as alternatives, the cost is referred to as project opportunity cost. Therefore, a similar approach and technique can be used to persuade organizations who are resisting combustion regulations once it is shown that there are benefits.

### 2.3 Process Simulation

Process simulation can be used as an important tool to investigate the influence of various process parameters and factors to implement the most efficient production method. The simulation model is normally reconfigured and experimented with for processes which are either expensive or impractical to do in the system it represents (Maria 1997). Simulation is preferably used before a system is newly built in order to curb the chances of failure to meet certain standards, to eradicate unanticipated hindrances, to prevent waste expenditure and to optimize a system.

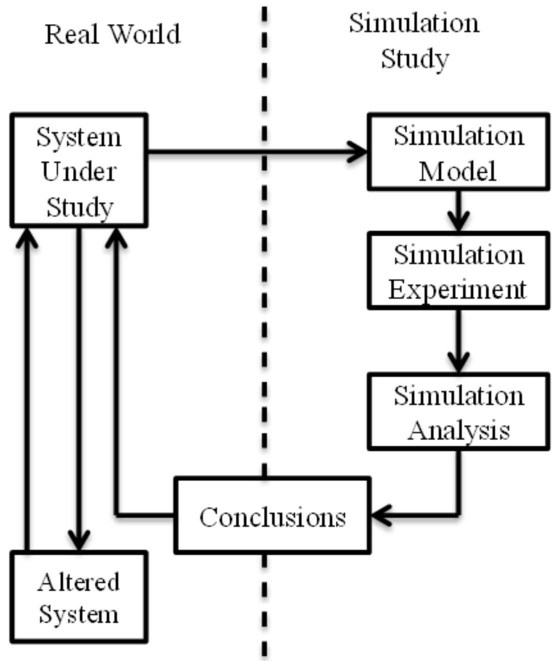


Figure 3. Simulation study schematic (Maria 1997)

Figure 3 shows schematic of simulation study. The process begins with an existing system which needs to be investigated under various operating parameters. The existing system is simulated in the computerized model. Influence of various parameters is investigated until the best yield is obtained under optimum conditions. Thermo-processing equipment safety standards in some way affects or alters the combustion process, therefore it is important to know what changes these standards will bring before implementation. This technique can answer many questions that managers pose to regulatory agencies. Many companies have asked if these standards will add value to their operations, while the response is yes, it is still to be proven.

### 2.4 Financial Modelling

Financial modelling is one way to investigate if a project has return on investment. In the beginning of any project, project managers must inform management and stakeholders about the risks assumed and the firm's capacity to finance the project. The managers have a responsibility to evaluate the financial capability and technological availability of each project they plan to undertake. In the instance where there are either financial or technological constraints, the project is abandoned. Garcia-Quevedo et al. (2017) reported that the biggest factor in project failures is the lack financial planning. To circumvent this challenge, it is required of any institution to conduct a detailed financial model to predict any financial outcome of a project during and after its implementation. Implementation of safety standards are considered as projects as they need to be financed. Normally firms implement projects with a view of expecting financial returns so that the debt of the project can be paid back. Genero (2005) defines project finance as the financing of long-term infrastructure, industrial projects and public services based upon a non-recourse or limited recourse financial structure where project debt and equity used to finance the project are paid back from the cash flow generated by the project. Genero (2005) mentioned that financial modeling in project finance is increasingly emerging world-wide as a preferred tool to fund projects. It is for this reason that a financial model is one of the critical elements of regulatory analysis.

## 3. Methods

The objective of this study is to develop cost-benefit model for thermo-processing equipment regulatory analysis through a combination of techniques. These techniques include process simulation, financial modelling and cost-benefit analysis. In this analysis, non-compliant and compliant combustion burner systems are compared. The two systems are studied in a form of case studies. A non-complaint system is a traditional and old way of operating a combustion system without any safety features and burner management while a compliant one has these added features as stipulated in SANS 329, NFPA 86 or EN 746.

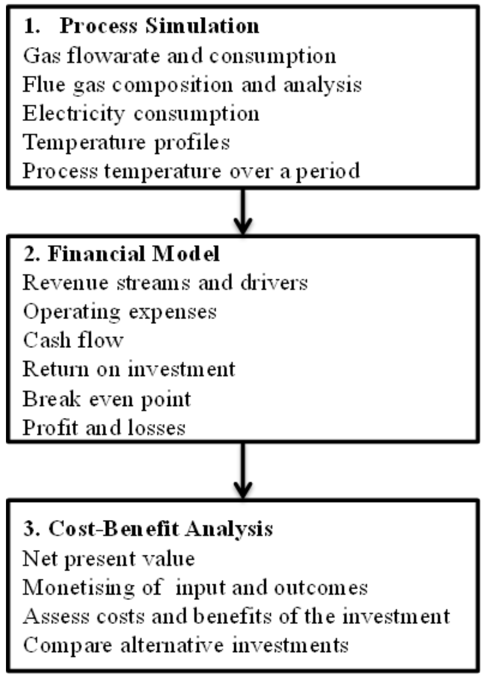


Figure 4. Methodology followed for this study

Figure 4 shows the three major steps to developing the CBA model. The first step is to simulate the existing non-compliant and compliant burner system on Flownex® Simulation Software. Other equivalent softwares such as Fluent or Ansys can be used to simulate the systems. For the non-compliant system the process conditions are set on the model to represent the existing site conditions. The compliant system is simulated following the guidelines from the burner supplier's manuals, combustion theory and as well as the safety standard itself. The main outputs and drivers of the model are gas consumption, electricity consumption, flue gas composition and process temperature. Once the output parameters of the model are recorded, they are then fed into the financial model and interpreted in monetary values as operational costs. Capital expenditure must also be estimated and put in the financial model. The difference in costs of the two systems is considered as savings or losses. Savings in this instance are considered as source of revenue as no actual products are sold from implementing this project. The savings are considered as tangible benefits of the project and are used to pay back the debt. Once all costs and benefits are quantified they are then compared in CBA model. The CBA model comprises of four decision making techniques. These techniques include the NPV, the benefit-cost ratio (CBR), the internal rate of return (IRR) and the multi-criteria decision analysis (MCDA).

### 3.1 Process Simulation

The non-compliant and compliant systems are simulated on Flownex as shown by Figure 5 and 6 respectively. The process parameters for the non-compliant system such as air and gas flow rates are taken as they are from an existing system while for the compliant system the process parameters are obtained from the burner manufacturer's guidelines, combustion theory and the safety standard.

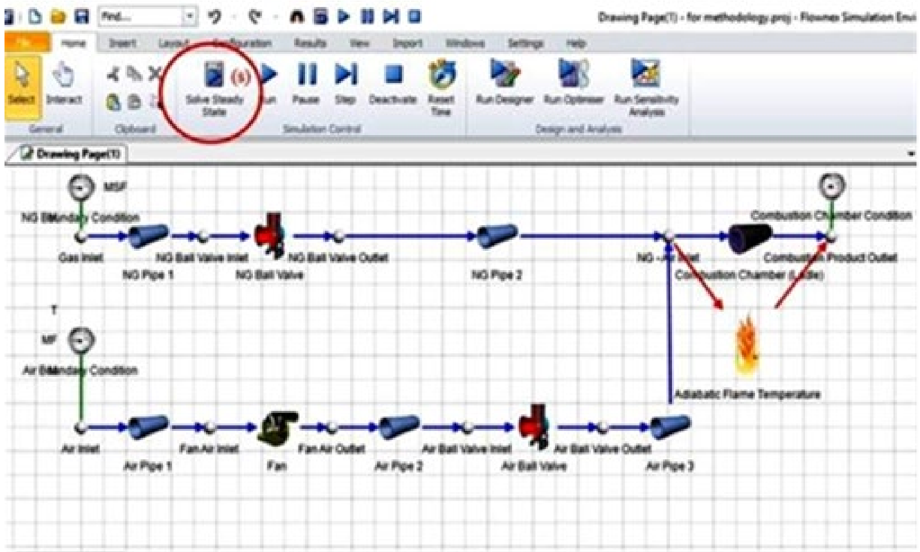


Figure 5. Non-compliant burner system

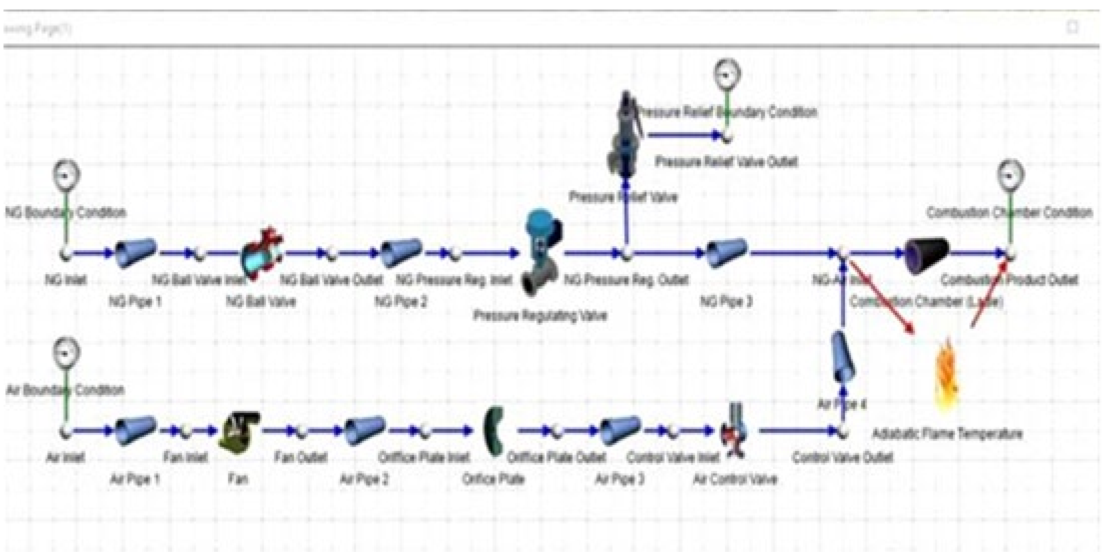


Figure 6. Compliant burner system

A recent survey conducted at firm which was used as a case study showed that a non-compliant system operates as shown in Table 1.

Table 1. Process input parameters

| Parameter | Compliant | Non-compliant |
|---|---|---|
| Gas Flowrate | 0.034 kg/s | 0.038 kg/s |
| Air Flowrate | 0.522 kg/s | 0.227 kg/s |
| Air/Fuel Ratio (v/v) | 10.5:1 | 4:1 |
| Flame Temperature | 1703 °C | 658 ° C |

An immediate observation is that a non-compliant system uses more gas even though a low flame temperature is achieved. This is because the system has no air-to-fuel ratio control which is very important for efficient combustion to occur and is stipulated in the safety standards.

### 3.2 Process Simulation

Financial model of a combustion system takes into consideration two main costs which are capital costs and operational cost. Savings or losses are considered as source of revenue. If the there are no savings and the financial projection shows a loss throughout, then the project should be rejected immediately. In case of safety, the project cannot be rejected, however, it should be noted that the project has no financial benefits even though it might bring intangible benefits.

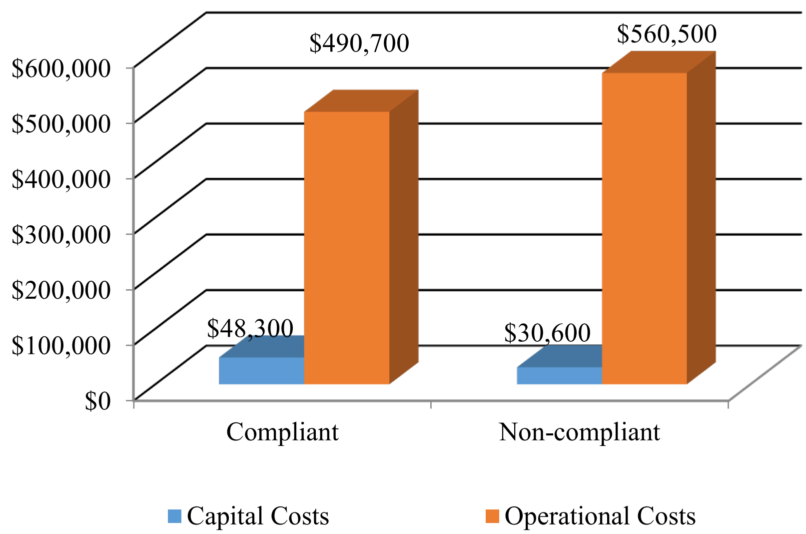


Figure 7. Capital and operational costs

Figure 7 shows the operational costs of a compliant and non-compliant system. This case study showed that the capital costs of a compliant system may look unattractive however the operating costs can be reduced due to added feature which not only make the system safe to operate, but to operate efficiently as well. The savings which result from the operating costs of the system is considered as source of revenue. Just like any other revenue, this income must be taxed. Once all the source of revenue and expenses are defined an income and cash flow statements can be conducted. To determine the break-even point of the project a cumulative cash flow cure is plotted as shown by figure 8. A project is considered to be profitable if it breaks even and becomes profitable over a period. The cash flow starts the negative side because of capital expenditure at the beginning of the project. Subsequent to commissioning the system starts generating savings or revenue. The savings are used to service the debt. The break-even period can differ depending on the profitability and availability of cash flow.

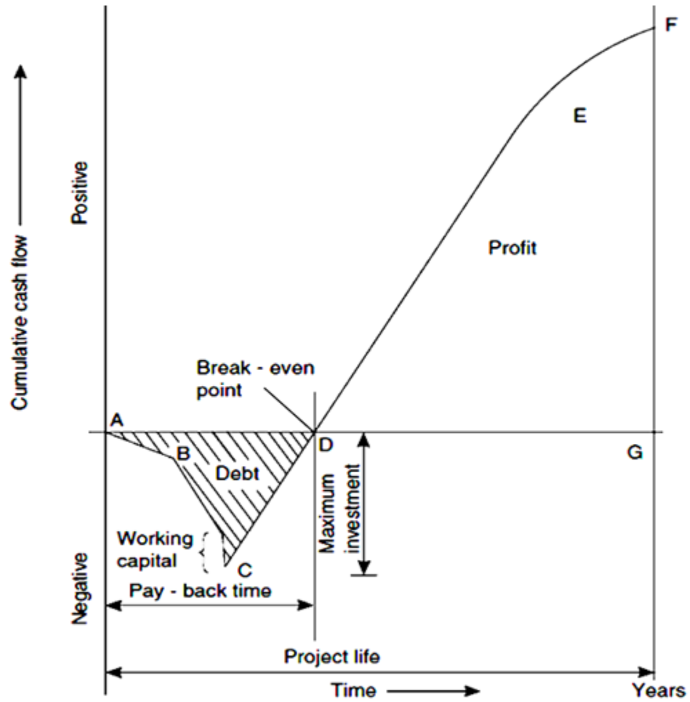


Figure 8. Typical cumulative cash flow of a project

### 3.3 Cost-benefit analysis

The CBA model assesses the cost and benefits of the compliant and non-compliant system. This is done by calculating the NPV of costs and benefits. Thereafter the NPV of net cash flow of the project is calculated. The other analysis decision making tool include BCR, IRR and MCDA.

*Net Present Value*

The NPV of a project simply expresses the difference between the discounted present value of future benefits and the discounted present value of future costs. The NPV decision criterion is indicated by equation 1.

$$NPV = PV(Benefits) - PV(Costs) \quad (1)$$

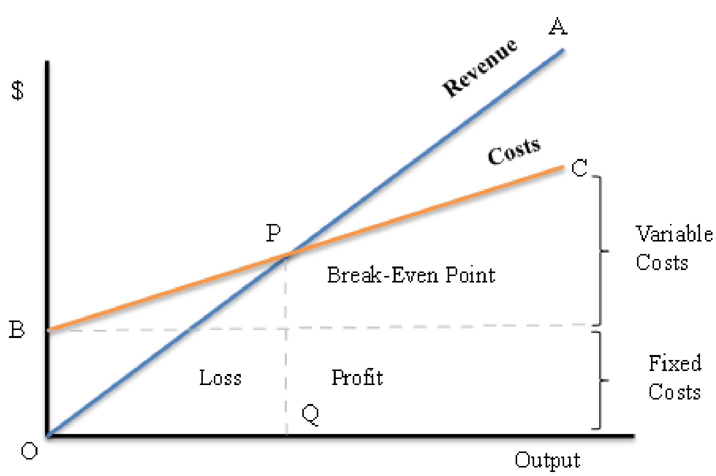


Figure 9. CBA curve

A positive NPV value for a given project suggests that the project benefits are greater than its costs, and vice versa. If NPV > 0, the project must be implemented, and if NPV < 0, the project must be rejected. When comparing different alternatives, if NPV(A) > NPV(B), project A must be chosen and vice versa. In this instance it will be the NPV(Compliant) and NPV(Non-compliant). The NPV(Benefits) and NPV(Costs) are plotted to assess the profitability of the project. The point where the two curves intersect is the break-even point. If the NPV(Benefits) curve remains below the NPV(Costs) then the project is rendered unbeneficial and it must be rejected.

*Benefit-Cost Ratio*

BCR is another form of the NPV decision making criteria. It is another way of comparing the present value of a project's costs with the present value of its benefits. Instead of calculating the NPV by subtracting the PV of Costs from the PV of Benefits, the PV of benefits is divided by the PV of costs as shown by equation 2

$$BCR = \frac{PV(Benefits)}{PV(Costs)} \qquad (2)$$

If this ratio is equal to or greater than zero, then the project can be implemented. If it is less than zero, then the project must be rejected. It must also be noted that when NPV > 0, then BCR > 1 and when NPV < 0, then BCR < 1. However, when ranking two alternative projects, the NPV rule takes precedence as the BCR can give incorrect results.

*Internal Rate of Return*

The IRR is a point where the discount rate at which the NPV becomes 0 on the cumulative NPV curve. The IRR is shown by equation 3.

$$CF_0 + \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} = 0 \qquad (3)$$

Once the IRR of an investment is known, it can be compared with the cost of financing the project. When the IRR, is greater than the cost of financing the project, the project should be implemented. When the IRR is less than the cost of finance, the project should be rejected. In this instance the cost of finance is the interest rate on capital costs of the project.

*Multi-Criteria Decision Analysis*

MCDA is both an approach and a set of techniques, with the goal of providing an overall ordering of options, from the most preferred to the least preferred option. MCDA is very helpful when comparing non-monetary benefits. MCDA uses multiple criteria which are first weighted according to their priority to meet the objectives of the project. The criteria are then scored from 1 to 10. The overall weighted scores of the multiple criteria are then averaged to compare different alternatives.

The main objectives of safety standards are process safety, occupational safety and environmental protection hence they are weighted more. The government is concerned about the safety of workers and protection of the environment while the firms might be concerned by the process efficiency. Therefore, depending on which regulation or standard is being assed, the criteria weight will differ.

Table 2. Multi-criteria decision analysis

| | | Compliant | | Non-compliant | |
|---|---|---|---|---|---|
| Criteria | Weight | Score | Weighted Score | Score | Weighted Score |
| Process Safety | 45% | 9 | 4.05 | 4 | 1.8 |
| Occupational Health | 25% | 10 | 2.5 | 2 | 0.5 |
| Environmental Protection | 10% | 9 | 0.9 | 2 | 0.2 |
| Ease of Operation | 5% | 8 | 0.4 | 5 | 0.25 |
| System Efficiency | 10% | 9 | 0.9 | 4 | 0.4 |
| System Reliability | 5% | 8 | 0.4 | 5 | 0.25 |
| Average Weighted Score | | | 9.15 | | 3.4 |

Table 2 shows an example of a case study using a MCDA to select which project should be preferred. The scoring of an MCDA is conducted by a panel of decision makers or an individual who is tasked to make the decision. A compliant system is scored higher on because the process is automated, it is safe, it prevents harmful emissions and therefore it protects the environment. This because of a ratio-controlled combustion which results in a complete combustion and higher efficiency. The computerized sequence of opening valves ensures that no fuel is wasted or released to the atmosphere.

A non-compliant system is manually controlled there is a possibility of operating at an incorrect air-to-fuel ratio. Furthermore, the compliant system is easy-to-operate due to a burner management system which controls the sequence of the process while a non-compliant system does not have this feature. System reliability is tricky since addition of more instrumentation can result in a lot of failures which from a maintenance point of view, the compliant system might look unattractive. Therefore, a higher weighted average score of 9.15 indicates that a compliant system should be preferred.

## 4. Conclusion

Safety regulations are important to manage risks in industrial activities. Often, they face resistance due to unjustifiable high compliance costs and intense administration requirements. To curb this perception a CBA model can be used to analyse the benefits and educate firms. A process simulation is a method which can be used to investigate the effect of the alterations that comes with regulation on the process. This is a simple method to substitute very costly and timeous experimentation. Once all the alterations in the operation of process are know they can be translated in monetary terms using a financial model to investigate their effect on the cash flow of the firm.

NPV, BCR and IRR are also useful tools to also aid in decision making process by investigating whether regulatory compliance is financially beneficial. If NPV>0, the project must be implemented, and if NPV <0, the project must be rejected. When comparing different alternatives, if NPV(A) > NPV(B), project A must be chosen and vice versa. Same applies to BCR, if BCR > 1, the project must be implemented, if BCR < 1, the project must be rejected. When the IRR, is greater than the cost of financing the project, the project should be implemented. MCDA is suitable to assess intangible benefits of different alternatives. An alternative with a higher averaged weighted score should be preferred.

However, safety is considered a non-negotiable principle in a workplace. Even if a CBA study can prove that a safety regulation is not financially beneficial to the firm, the regulation must still be complied with. However, management of firm will make informed decision and implementing safety project knowing exactly what to expect. The model can be useful as well to regulatory agencies to make their own assessment as well prior to releasing new regulation and enforcing.

## 5. Acknowledgement

The authors gratefully acknowledge the National Research Foundation for proving financial support to the first author. The University of Johannesburg is also acknowledged for providing access to literature, data and information through the library. The authors lastly acknowledge Esteq (Pty) Ltd. for providing an operating license for Flownex® Simulation Software, training and all the assistance offered.

## References

Arewa, A. O., and Farrell. P, A review of compliance with health and safety regulations and economic performance in small and medium construction enterprises, *In: Smith, S.D (Ed) Procs 28th Annual ARCOM Conference*, 3-5, Edinburgh, UK, Association of Researchers in Construction Management, pp. 423 – 432, 2012.

Baksi. S., and Bose. P., Informal sector, regulatory compliance, and leakage, *Journal of Development Economics*, vol. 121, pp. 166 – 176, 2016

Blind. K., *The Impact of Regulation on Innovation,* Manchester Institute of Innovation Research, United Kingdom, 2012.

Campbell. H. F., and Brown. R. P. C., *Benefit-Cost Analysis: Financial and Economic Appraisal using Spreadsheets*, Cambridge University Press, New York, 2003.

Crain. N. V., and Crain. W. M., *The Impact of Regulatory Costs on Small Firms Report to Small Business Administration*, Office of Advocacy, Lafayette College, Easton, PA, 2010.

Dahl. O, Fenstad. J., and Kongsvik. T., Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach, *Marine Policy & Management*, vol. 41, pp. 20-41, 2013.

Dahle. I. B, Dybvig. G., Ersdal. G, Guldbrandsen. T., Hanson. B. A., Tharaldsen. J. E., and Wigg. A. S., Major accidents and their consequences for risk regulation, *Advances in Safety, Reliability and Risk Management*, London, 2012.

Dudley. S. E., and Brito. J., *Regulation: A Primer*, Mercatus Center, George Mason University, United States of America, 2012.

Dudley. S. E., Fraas. A. G., and Mannix. B. F., The Office of Management and Budget's Draft 2010 Report to Congress on the Benefits and Costs of Federal Regulations, research brief, Regulatory Studies Center at George Washington University, Environmental Protection Agency, Improving on Regulation: Final Plan for Periodic Retrospective Reviews of Existing Regulations, 2010.

Fairman. R., and Yapp. C., Enforced self-regulation, prescription, and conceptions of compliance within small businesses: the impact of enforcement, *Law & Policy*, vol. 27, no. 4, pp. 491-519, 2005.

Flin. R., Mearns. K., O'Connor. P., and Bryden. R., Measuring safety climate: identifying the common features, *Safety Science*, vol. 34, pp. 177–192, 2000.

Garcia-Quevedo. J., Segarra-Blasco. A., and Teruel. M., Financial constraints and failure of innovation projects, Technological Forecasting & Social Change. Available: http://dx.org/10.1016/j.techfore.2017.05.029, 2017

Genero. M., Financial Modeling of Project Financing Transactions, Deloitte Consulting, Milan, 2005.

Hale. A., Borys. D., and Adams. M., Safety regulation: The lessons of workplace safety rule management for managing the regulatory burden, *Safety Science*, vol. 71, pp. 112–122, 2015.

Hanley. N., Environmental Cost-Benefit Analysis, *Encyclopedia of Energy, Natural Resource and Environmental Economics*, pp. 17-24, 2013.

Hayes. J., Operator competence and capacity – lessons from the Montanra blowout, *Safety Science*, vol. 50, pp. 424-574, 2012.

Hopkins. A., *Failure to Learn: the Texas City Refinery Disaster*. CCH, Sydney, 2008.

Hopkins. A., The cost-benefit hurdle for safety case regulation, *Safety Science*, vol. 77, pp 95 – 101, 2015.

Johnson. C. W., Economic recession and a crisis of regulation in safety-critical industries, *Safety Science*, vol. 68, pp. 153 – 160, 2014.

Johnstone. R., and Sarre. R., "Regulation: Enforcement and Compliance", *Research and Public Policy Series*, Australian Institute of Criminology, vol. 57, pp. 4-9, 2004.

Kvalheim. S. A., and Dahl. O., Safety compliance and safety climate: A repeated cross-sectional study in the oil and gas industry, *Journal of Safety Research*, vol. 59, pp. 33 – 41, 2016.

Kwon. O. J., and Kim. Y. S., An analysis of safeness of work environment in Korean manufacturing: the "safety climate" perspective, *Safety Science*, vol. 53, pp. 233-239, 2013.

Loosemore. M., and Andonakis. N, Barriers to implementing OHS reforms the experiences of small subcontractors in the Australian Construction Industry, *International Journal of Project Management*, vol. 25, pp. 579–588, 2007.

Liu. X., Feng. H., Chen. L., Qin. X., and Sun. F., Hot metal yield of a blast furnace on constructal theory, *Energy*, vol. 104, pp 33 – 41, 2016.

Livemore. M.A., Glusman. A. J., and Moyano. G., *The Globalization of Cost-Benefit Analysis in Environmental Policy*, Oxford University Press, USA, 2013.

Lu. C. S., and Yang. C. S., Safety leadership and safety behaviour in container terminal operations, *Safety Science*, vol. 48, pp. 123-134, 2010.

Majumdar. S. K., and Marcus. A. A., Rules versus discretion: the productivity consequences of flexible regulation, *Academy of Management Journal*, vol. 44, no. 1, pp. 170-179, 2000.

Manahan. M., Inspection & Testing of Combustion Safeguards for Fuel-Fired Equipment, Allianz Global Corporate & Specialty AG, vol. 6, 2012.

Maria. A., Introduction to modeling and simulation, Proceedings of the 1997 Winter Simulation Conference, State University of New York at Binghamton, 1997.

Stavrianidis. P., Map Your Way to Strategic Investments in Process Safety, 2001.

Walker. K, Poore. W., and Eales. M., Improving the opportunity for learning from industry safety data. SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, pp. 11–13, 2012

Windapo. A. O., Investigation into the Level of Compliance to Construction Health and Safety Requirements within the South African Construction Industry, Construction Economics and Management Department, University of Cape Town, South Africa, pp. 2 – 11, 2012.

## Biography

**Motshumi Joseph Diphare** holds a Master's degree in Chemical Engineering and a DPhil in Engineering Management from the University of Johannesburg. He is a recipient of several awards and scholarships for his academic excellence. His research interests are process safety, industrial safety standards, waste recycling, waste-to-energy, environmental studies specifically in waste lubricants and hydrocarbons. He has published **10** international peer reviewed and refereed scientific articles. He has co-supervised **8** Bachelor degree research students. During his tertiary studies, Motshumi established himself as a self-starter and leader through his volunteer experiences. He was elected as the chairman of the Chemical Engineering Student Association. He has over 8 years industirial experience and is currently a Senior Applications Engineer for Slurry Valves & Piping Systems at Weir Minerals Africa & Middle East