INFORMATION THROUGH THE PIPELINE INVESTIGATING IS-RELATED ISSUES IN THREE PIPELINE EXPLOSIONS

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L'auteur a reçu le prix ABD-BVD 2017 pour son travail de fin d'études intitulé *Information through the Pipeline: Investigating IS-Related Issues in Three Pipeline Explosions*, présenté en juin 2016 à l'Université Libre de Bruxelles (ULB) en vue de l'obtention du titre de Master en sciences et technologies de l'information et de la communication. Cet article aborde quelques points forts de ce travail.

De auteur mocht de ABD-BVD Prijs 2017 in ontvangst nemen voor zijn eindwerk getiteld *Information through the Pipeline: Investigating IS-Related Issues in Three Pipeline Explosions*, hetwelk werd verdedigd in juni 2016 in de Université Libre de Bruxelles (ULB) te Brussel, teneinde het behalen van Master en sciences et technologies de l'information et de la communication. Dit artikel haalt een paar sterke punten aan van dit werk.

■ The present article discusses the impact of information sciences-related issues upon gas pipeline explosions. In order to do so, the discussion first clarifies the notion of information sciences, and presents a sample of disciplines (project management, knowledge management and data quality) within that broad, complex realm. For each of these disciplines, salient symptoms of issues will be selected, and exposed. Afterwards, the paper will determine the specific segment of the gas business that will come to attention, and the main causes of explosions that affect it. In order to offer a complete overview of these issues in pipeline explosions and appreciate the impact of IS-related issues upon these disasters., the paper will research these symptoms in one incident report for each cause (one in Canada, one in the US and one in the European Union).

■ L'article qui suit traite de l'impact de problèmes liés aux sciences de l'information sur les explosions de pipelines de gaz. Afin d'y parvenir, la discussion clarifie d'abord la notion de sciences de l'information, et présente un échantillon de disciplines dans ce domaine à la fois vaste et complexe (la gestion de projet, la gestion des connaissances et la qualité des données). Pour chacune d'entre elles, des symptômes problématiques vont être sélectionnés, puis exposés. L'article déterminera ensuite la partie spécifique de l'industrie du gaz qui sera au centre de l'attention, ainsi que les causes principales d'explosions qui affectent celle-ci. Dans le but d'offrir un aperçu complet de ces problèmes dans les explosions de pipelines et de pouvoir juger de leur impact, l'article portera sur la présence de ces symptômes dans trois rapports d'accidents (un au Canada, un aux États-Unis d'Amérique, et un dans l'Union Européenne) qui traitent des trois causes.

■ Dit artikel bespreekt de impact van problemen verbonden met informatiewetenschappen bij ontploffingen van gaspijplijnen. In eerste instantie wordt uitleg gegeven over de notie informatiewetenschappen, en komt een waaier van disciplines aan bod (projectbeheer, kennisbeheer en gegevenskwaliteit) binnen dit ruime, complexe domein. Voor elk van deze disciplines worden treffende symptomen van problemen geselecteerd en toegelicht. Daarna bepaalt de verhandeling het specifieke segment van de gassector dat onder de aandacht wordt gebracht, en de belangrijkste oorzaken van ontploffingen die er zich voordoen. Om een volledig overzicht te bieden van deze problemen op het vlak van ontploffingen in pijplijnen en de impact van problemen verbonden met informatiewetenschappen bij deze rampen te beoordelen, onderzoekt de verhandeling deze symptomen in één incidentverslag voor elke oorzaak (één in Canada, één in de VS en één in de Europese Unie).

The consequences of inadequate documentation should never be neglected: in any business or activity, the impossibility to reach proper information can leave critical elements unnoticed, and this can be home to undesired situations –if not catastrophes. In that regard, a question worth examining is the extent to which the gas industry is impacted by information sciences-related issues, and if pipeline explosions are resulting disasters. In order to determine the correlation between information sciences (IS) and pipeline explosions, the present article will first expose this vast scientific discipline and the complex energy business. Once both have been made clearer, the IS-related issues found in field studies and the main causes of pipeline explosions will be analyzed and confronted to each other, so as to find a possible common denominator.

The examination will define these issues, and research their presence in pipeline explosions so as to shed a new light on these disasters. However, constraints in terms of length will limit the scope to these questions only, and will not allow for discussing a concrete application of practical solutions to these IS-related issues –even though these exist, notably under the form of constructive practical recommendations.

Insight on IS: Disciplines and Related Issues

IS are, interestingly, difficult to define: they are indeed so pervasive and widespread that no single feature allows for them to be entirely described[1]. All their aspects are embedded in "a morass of data ranging from highly technical facts describing the objective features of the technical system to conflicting perceptions, opinions, and spontaneous remarks voiced by the human participants in the social system"[2]. As a result, problems could be caused "by multiple factors, such as unrealistic expectations, lack of resources, uncooperative customers, and weak management of contractors" just to name a few[3]: for that reason, our understanding of IS will only be limited to several salient disciplines –Information Technologies (IT) projects, Data Quality and Knowledge Management (KM)–, and their issues restricted to acknowledged problematic symptoms.

IT Project Management

An information system –a computer program, typically— is the eventual materialization of a successful IT project, and there is unfortunately no guarantee that the efforts devoted to the creation of the product are rewarded: in the sole year of 2002, more than $55 billion "were wasted in failed information technology" in the United States[4]. The success of an IT project rests on a subtle balance between cost goals, time goals and project performance[5] but, then again, addressing these constraints does not prevent its later failure due to other symptoms, such as these:

Correspondence Failure

This occurs if the system designed fails to meet the objectives it was originally initiated for, and this in spite of a cost-benefit analysis[6].

Process Failure

Whenever the IS fails to develop in an allocated budget, time schedule, or both, failure can be described as procedural. This concerns developed systems that are not workable, but also workable systems if the cost and time to produce them reach excessively beyond their initial means[7].

Interaction Failure

Triggering too little interest or satisfaction from the users is a form of failure in its own right. An information system might be "technically sound with specifications met", but nothing guarantees that it will not be met "with resistance or rejection by the users or corporate management"[8].

Expectation Failure

An information system is created for stakeholders, i.e. persons "who have a vested interest in [it]"; these can be "systems analysts, various classes of end-users, sponsors, external users (e.g. customers), legislators etc."[9]. Their values as well as their expectations or requirements from the system might be unsatisfied in many ways, and this is what an expectation failure describes[10].

Knowledge Management (KM)

A second discipline within IS is knowledge management. It can be described as "the ability to interpret and integrate information with one's own experience so as to create capacity for action"[11]. The angle of KM as a source of IS-related issues is relevant, notably since it is deeply rooted in the organizational culture, the process and the technologies of a company[12]. Besides, KM aims to limit the impact of organizational records getting lost or becoming "difficult to access", and of "[o]rganizational members [leaving] and [taking] their knowledge with them"[13]. The case of a petrochemical plant on the Texas Gulf Coast offers a convincing illustration for this: successive waves of retirement left the company with inexperienced workers, among whom an operator who made a mistake causing an explosion after several months of service[14]. Managers deplore knowledge loss, but too few companies have developed successful strategies assuring a better diffusion of knowledge throughout groups, divisions, departments and functions[15]. Paying attention to the following symptoms is a right start:

Reinventing the Wheel

This is observable if a team devotes considerable efforts to produce something that has been done by another team in the past –e.g., Ford Motor Company's inability to repeat the success of its Taurus model design team on account of lost knowledge[16].

Not Invented Here

An important point of knowledge sharing is its dynamism within the company not only between individuals, but also between groups[17]. This issue occurs whenever a team refuses to adopt an innovation from another one because its members view it as inapplicable to them.

Underwhelmed

This occurs if the medium for innovation and changes –such as memos, speeches or Webpages– do not lead to enthusiastic adoption behaviors of innovations[18]; in some sense, this resembles the

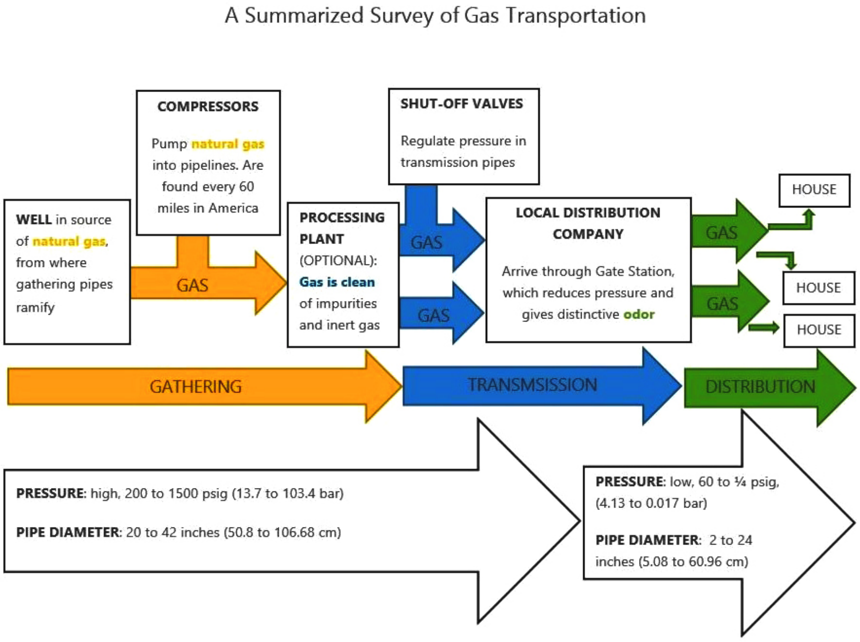

Fig. 1: A Summarized Survey of Gas Transportation.

issue presented as the interaction failure in project management.

Failed attempts of "fast followers"

A team is convinced by the success of another one, but they find themselves helpless in trying to reach the same objective; this happens typically because they do not provide realistic efforts due to a lack of details[19].

Arrogance

Knowledge can emerge if the member of a group makes comments that stimulate the imagination of other members, or if two members with conflicting views lead a third one to suggest an alternative that reconciles their viewpoints[20]. Conversely, if people are certain of knowing that they do not want to learn anything new anymore, this behavior is described as arrogance[21].

Invisible Symptoms

These are the most difficult ones to observe –hence the name–, but they cover a wide range including lack of curiosity and confidence among other things[22].

Data Quality

In brief terms, a data corresponds to an {e,a,v} triple: the value v –e.g., "Spain"– exists within the domain of definition of an attribute a –e.g., a column named "Countries of the EU"– that exists in an entity e –e.g., the spreadsheet "Countries"[23]. Data quality corresponds to its "satisfy[ing] the requirements of its intended use", and can be considered as of poor quality "to the extent that [some data] does not satisfy the requirement"[24]. In that case, substituting "Spain" for "Earth" would be immediately noticed as unfit –it is no country–; still, data unfit for use can be much harder to notice –a good example would be incorrect numbers in a column where a numeric value is expected. Remarkably, at least 60% of enterprises suffer from data quality problems: "10–30% of data in organizational databases are inaccurate" and "industrial data error rate of 75% can be found, 70% of manufacturing orders are assessed as of poor data quality"[25]. Symptoms of poor data quality include:

Ghost factories

Data of poor quality represents a dry loss on two accounts: it requires manpower –i.e. time and money allotted by a company— to both produce the defaults and correct them[26]. These wasted efforts can be described as ghost factories.

"Use It or Lose It"

In some sense, data can be compared to used cars: the more frequently they are driven, the more they visit a carwash[27]. Conversely, scarcely used data escape rectification –so use them, or lose them.

Insufficient attention to documentation and processes

Simply put, this feature can be summarized as the lack of adequacy in the recording methods[28].

Insufficient attention to data governance in the long run

As time changes the world that the data must accurately reflect[29], it also alters "the database structures, schema, and sources of data" and even "the social forces that determine what information needs to be in the database", thus making insignificant the all-important, and vice versa[30]. In short, this symptom is the failure to consider the impact of time upon data.

The Gas Business and Pipeline Explosions

Similarly to information sciences, the gas business is vast and requires limitations for the study to be clear. The nature of the gas network illustrates this, for instance, since there is more to it than a simple end-to-end collation of the same type of pipe. Some pipes collect gas from production areas to provide them to processing facilities –hence the name, gathering pipes– ; the second type, transmission pipes, carry hazardous liquid and gas to communities as well as large-volume users and, finally, distribution pipes split from transmission pipes to end users[31]. These pipes respond to different needs, and have different tolerance thresholds –which are summarized as follows[32,33] (see Fig. 1).

In this study, only transmission pipes will come to attention: yet, the numerous protagonists involved around transmission still leave room for too many perspectives and countless interactions. The focus will therefore be put on the operator –i.e. the company that buys purified gas and supervises its safe transport through the transmission network to the local distribution companies who, in turn, provide it to commercial and residential customers[34]. In short, only explosions happening to transmission pipelines under the supervision of an operator will come to attention –which implies defining the causes of a pipeline explosion.

Causes of explosions

Admittedly, the impact of IS-related issues upon pipeline explosions can only be appreciated in the light of how considerable these are in the predominant causes. Then again, these causes may vary both in nature and in frequency according to the country or the region. Studies demonstrate that in the three regions of the world to be investigated –the United States (US), Canada and the European Union (EU) –, the main causes are roughly the same, and concern all types of pipelines:

Third-party damage

The typical example of third-party damage occurs when the digger driver of a contracting company performs ground works near or above the network, and inadvertently damages it[35].

Corrosion

Corrosion can affect the inside as well as the outside of the pipe: external corrosion originates in the contact of the underground network with either the soil, a source of freshwater or seawater, all of which contain carbon dioxide and corrosion-causing bacteria; it is therefore far more frequent than internal corrosion[36]. Internal corrosion does not concern transmission pipelines since it originates in a contact between the inner coating of the pipe and gases that are sour and unrefined –and transmission pipes only transport refine gas[37].

Material defaults

This encompasses any manufacturing default affecting the parts of the pipeline assembled in the line. Interestingly, defaults in a pipe can be detected, but the cost of reparations for minor cracks sometimes leads to wait for them to be more serious so as to justify the renovation[38].

In the US, Canada and the EU, these causes are all the most salient in the transmission network[39,40,41] –in the US and Europe only, these three causes amounted, among a dozen others, for more than 70% of all occurrences between 2009 and 2016[42,43]. These can be therefore described as the main causes of pipeline explosions for the study and, at this stage, it is now possible to determine the role of IS in pipeline explosions. It will indeed be established whenever the symptoms are found in three reports of pipeline explosions, which occurred –as expected– in the US, Canada and Europe, and that originate in the three main causes presented.

Third Party Aggression: Ghislenghien (Belgium)

The incident in Ghislenghien occurred on July 30th, 2004 in Belgium, and can be very briefly summarized[44]: a ground stabilizer drove "over or near to the pipeline", and accidentally touched the segment that would later explode in the course of that maneuver[45,46]. The damaged pipeline was not pierced on the spot, but the aggression resulted in an insidious region of lower resistance to pressure on the outside of the pipeline, where only 3 or 4 mm remained out of the 13 mm steel tube[47]. Pressure changes caused a leak, which made the ground shake: fire and police department arrived, but they could not prevent the explosion that would kill twenty-four, wound one hundred thirty-two, and cause losses estimated to 100 million euros in total[48].

What first strikes in this narrative is that the operator did not notice the leak. One might indeed expect red lights and sirens to start in the control room because of the pressure drop and, as a result, immediate response system or data management could be expected as a part of the problem. Still, this did not happen because the leak was absolutely undetectable out of two reasons: firstly, it was not profuse at that moment and, secondly, the 60 bars of pressure causing the perforation were significantly under the tolerance threshold of the pipeline[49]. A fire expert specialized in gas explosions points out that "a gas leak could have started a long time before the incident" without being noticed under such circumstances: the explosion derives from the gas accumulation originating in a leak that is much too small for anyone to notice –and this impossibility to detect also left the central data center in Brussels unaware of the issue[50].

A second hypothesis might be that the data provided by the operator were incorrect, and led the contractor to dig in the wrong place: indeed, the pipes are buried 0.9 meters deep in the ground, and if the given geographical location is wrong, the marking poles might mark a spot where there is no pipeline underneath[51]. The contractor could then pierce the pipe which has not been marked because of these wrong coordinates: this seems consistent with a version of the incident presented by the news reporters, that states that the firefighters had received incorrect locations of the pipeline before the explosion[52]. Then again, this version must be refuted since the operator Fluxys put up-to-date maps at the disposal of the contractor, and to the fire department in the event of an incident –firsthand interviews with a Fluxys employee and a fire commander-in-chief present on the Ghislenghien site after the explosion confirm this version[53,54].

Another reason that rules out inadequacy in the operator's information system is the quality of its ambitious system of data management: it covered pipelines ten meters by ten meters, and the IS contains, for every pipe, the day of fabrication, of installation, its certificates, the number of patrols over it, the works performed in its vicinity and the mail exchanges concerning the grant of permissions to contractors: its effectiveness was even rewarded by the prestigious Association for Information and Image Management –AIIM– International European Solution of the Year Award in 2000, which denotes a certain care for documentation matters[55].

In addition to an appropriate, effective IS, the operator Fluxys can also rightly be considered as a company that communicates well[56]: before the incident occurred, the operator had spontaneously informed more than 8,300 proprietors and contractors for them to avoid incidents, and recorded 56,000 requests for information concerning the danger of gas explosions[57]. Not only does the operator's system meet the stakeholders' expectations –by indicating the right location of a pipe and immediately providing clear and useful documentation to the prosecutor's bureau for the investigation[58]–, it also significantly appeased the tensions between Fluxys and the firefighters after the incident[59]: a fire chief considers that the reaction of the operator in regard of the situation after the incident was appropriate –and convinced the fire department of their ability to both avoid and manage that tragic type of situation on the basis of what they know[60].

As a matter of fact, finding IS-related issues that caused the explosion in Fluxys' management is not possible, because they are simply not responsible for it. The most probable scenario of the incident is that, obviously, "building sites managers insisted that all deadlines [were to] be met at any cost"[61]. This would have had the contractor work with less regard to these clearly and accurately delimited regions[62], and the segment hit by the machine was exactly the one indicated under the marker. The situation was elegantly presented during an interview with a former Fluxys employee in the following terms: "the person who had scratched the pipe either noticed he/she had done so –or did not notice–, and, whether he/she did, he/she might have afterwards informed his/her foreman –or, then again, might have not informed him/her–; the latter would have probably, in turn, decided to ignore this issue so as to avoid consequences –the only certainty being that no one will ever know what exactly occurred that day"[63].

If there should be only one IS-related issue in this tragedy, it would be a very slight expectation failure in the process –which is, then again, hardly imputable to Fluxys. When the firemen crew was en route to the explosion site, no one was aware that it was a pipeline incident in the first place: for all they knew, the explosion that occurred was a plane crash and, on his way to the incident perimeter, the fire commander was even told that the explosion took place in the nearby US Army base in Chièvres, a neighboring locality; moreover, his mobile phone was useless because the network was saturated, and there was purely and simply "[n]o way to know what was exactly going on"[64,65] –even though, as mentioned, the firefighters had correct maps at their disposal beforehand. However, the catastrophe happened in 2004: the availability of contemporary new mobile technologies such as tablets and smartphones –i.e. more than ten years after the incident– could have been used as effective alternatives to cellphones[66].

Corrosion: Engelhart (Canada)

In the same way to the narrative of Ghislenghien, the incident in Engelhart, near Ontario, can be very briefly summarized: a pipeline operated by TransCanada Pipeline Inc. ruptured on September, 12th 2009. The reason for this break –and the subsequent explosion– is the external corrosion of the polyethylene tape coating[67]. The Engelhart incident was quickly treated: after the rupture, the Supervisory control and data acquisition (SCADA) system received an alarm which had the operator close the valve, and led to an interruption of the gas flow –but, of course, not an extinction of the fire, as the evacuating gas had to burn away. This occurred only four minutes after the discovery of the leak[68].

The investigation reveals that the section where the explosion started shows a "tenting of the polyethylene exterior tape coating[...] over the longitudinal seam weld of the pipe" which was impaired by several small corrosion cracks; under the constant pressure of the gas flow, these gradually aggravated, turned into a greater single crack that eventually caused the rupture[69]. The explosion fortunately killed or injured nobody, but the damage caused enormous costs: 48.22 meters of pipeline had to be rebuilt, 3,420,000 m^3 of gas were released, and it took two days for the Aerial assistance from the Canadian Ministry of Natural Resources' Aviation, Forest Fire and Emergency Services to extinguish the flames that burned 25 hectares of forest and grassland[70].

At first sight, the role of IS-related issues seems plausible: operators use geographical information systems and data acquisition systems that inform about "the condition and availability of surface type as well as the proximity of power lines, railroads and third-party pipelines [or] data such as soil class, soil resistivity, leak history and [the] effectiveness [of the coating]"[71]. What first comes to mind is that the data led to insufficient inspection; still, this possibility is difficult to demonstrate in the light of the little documentation concerning the present case study. As a matter of fact, there is indeed no information in the sources concerning the data present in TransCanada's systems concerning corrosion. All that is known is that the system recorded data around seven criteria:

- Past hydrostatic tests and test failures –that is to say, what happened after high-pressured water is injected into the pipe in order to test its resistance[72];
- Operating performance of the pipeline;
- Expected crack growth rates and failure frequency;
- Potential failure consequences (i.e. risk analysis);
- Engineering limit state analysis –such as the SMYS (Specified Minimum Yield Strength) of the pipeline[73];
- SCC (Stress Corrosion Cracks) condition excavation data;
- Cathodic protection history –i.e., the state of the extern coating layer of the pipeline.

These elements are important as far as preventing corrosion is concerned, but both condition and availability of surface type seem more difficult to find among them: as a matter of fact, it is impossible to determine where information concerning soil class and resistivity fit in any of these categories, or if they are simply present in the system [Book, 2010]. In any case, the report mentions that the data were verified on an annual basis, and they were correct according to the investigators[74]. The report describes data as adequate, up-to-date: therefore, data quality is no issue.

Interestingly, there are also valid reasons to believe that the system was designed to store data that could prevent outer corrosion: the post-incident investigation reveals that the pipeline section had markings on the crack surface evidencing that the pipes had been hydrostatically tested[75]. The operator subjected the line to verification after a first failure happened in August 1985 with water during a test and, as a consequence, a stress corrosion cracking management hydrostatic retest program was initiated. High-pressured water was injected through the section to test its resistance in 1986, 1991, 1994, 1999 and 2004; even though a failure was noted in 1999, it received sufficient attention and documentation so as to let the 2004 test be completed safely and normally[76]. The availability of this information proves that the system is well-conceived, and responds to a pivotal expectation: drawing attention onto a fragilized pipe –or at least, most of it.

If verification covered most of the pipe, it was indeed insufficient as far as the lateral sides of the pipes are concerned: the in-line inspection tool was "not designed to identify the stress corrosion cracking in the longitudinal seam weld," and could not adequately discover from the inside corrosion that happen on the exterior surface of the pipe[77] –in other words, inspection methods were part of the problem. As a result, no data concerning the effects of outer corrosion on the lateral parts were considered, because the program relied on inadequate technologies. The explosion in Engelhart can be, to a certain degree, related to a "short-term vision during the conception of a project, the emphasis being put more often than not on purely technical aspects instead of the application domain"[78]. It seems possible that technologies and the corrosion surveillance program were seen as sufficient to the operator, who felt no need to conduct more complete investigation: in that case, it could be perceived as the KM-related invisible lack of curiosity preventing further, in-depth checks of the network. Otherwise, the ability to discover leaks in the past, the surveillance program and the advanced technologies might have led the operator to feel overconfident, and believe that acting more was simply superfluous: in that case, the KM-related issue could be considered as arrogance.

Construction Defect, Material and Equipment Failures: San Bruno (United States of America)

The pipeline explosion of San Bruno on September 9, 2010 started during a technical check on the device bringing constant electricity to the network data control –which provides flow rates, pressures, equipment status and, most importantly, that have an impact on the control valves, that can modify pressure if necessary[79]. As changing electric charge affects the data, the control room was in constant communication with the data-gathering center so as to inform them of the impact of data upon their collection[80]. During the operation, a circuit opened and blocked the flow of electricity to the transmitters: the resulting low-pressure signals led the automatic regulating valves to a full open position so as to compensate for this[81].

As a result, more than 60 exact high-pressure alarms were triggered within a few seconds, which the data-gatherers properly received, but not the control room: high pressure eventually culminated into the rupture of a "faulty, poorly welded pipeline" in line 132, which was placed in 1956 –the blatant defectiveness of which would not have met industry standards at the time even[82]. The incident had a particularly high toll: it resulted in the loss of 47.6 million standard cubic feet of natural gas[83], eight dead, ten serious and forty-eight minor injuries, the destruction of 38 homes and the damaging of 70 others; in addition to this, total costs amounted to $ 13,763,000 –$ 13,500,000 to repair the pipeline, $263,000 for the loss of natural gas[84].

Curiously, data issues had an unquestionable impact upon this explosion: the information system presented an overestimated resistance of the faulty segment –to 400 psig of pressure, whereas its actual limit was of 375[85] and the explosion occurred under a pressure of 386.12 psig[86]. That segment is also described as one 30-inch-diameter seamless steel pipe with a wall thickness of 0.375 inch that dates back to 1956, with a "manufacturer" recorded as unavailable[87]. In fact, the segment consisted of six short pipe segments of 3.5 to 4.7 feet long, and that were not seamless but double submerged arc welded pipes –i.e. they consisted of two parts held together thanks to "partially welded longitudinal seams"[88]. The presence of seams could have been discovered in the light of two precedents, Rancho Cordova, and another similar issue occurring in October 1988 about 9 miles away from San Bruno: records show that 12 feet of Line 132 –where the faulty segment would later explode– were replaced because of a "longitudinal defect": a report of material failure was to be prepared, but the operator Pacific Gas & Electricity (PG&E) was eventually unable to find this report and recorded the cause of the leak as "unknown"[89]. This demonstrates that three symptoms concerning data quality played a role in this explosion: firstly, insufficient attention to documentation –process recordings–; secondly, insufficient attention to data governance –i.e. failure to track the impact of time upon data– and thirdly, infrequent use of data as well –the "Use it or Lose It" symptom.

Besides, the explosion is also related to IS project management to the extent that the information system did not meet the users' expectations. The sole Line 132 was documented with 18,000 pages of various records, but the National Transport Security Board (NTSB) found out that pieces that are crucial to their investigation were missing: there were no radiography receipts for the faulty pipe, and the only 10 percent of the welds dating back to the 1948 construction which were radiographed did not capture much more than a few inches of every longitudinal seam weld[90]. Investigators also discovered that only 0.2 percent of the seams were actually recorded in total, and that 30 percent of the records of the system inspected in 2011 miss records[91]. Moreover, some recorded data could have been used to remedy the situation, but the operator "did not make use [of the data] at its disposal to revise threats"[92] –thus indicating a problem of interaction. This being said, nothing indicates that the system prevents to record adequate data at all –there is therefore no element pointing towards a correspondence failure.

However, knowledge management is also an element in the explosion: one of the invisible symptoms –lack of confidence– is underlined in the investigation report since there was a lack of delimitation both in the roles as well as responsibilities of the crew, thus having the staff not allocating time and attention "in the most effective manner", and shutting the valves more than 90 minutes after the explosion –whereas it was nearly immediate in the other two case studies–[93]; this explains both the unawareness of the incident at a large level and until rather late, but also the non-adequacy of their reaction. Lack of confidence is illustrated by the operator hesitating to shut off the valves, whereas less damage would have also resulted from immediate action[94]: as a matter of fact, he refused to do so by fear that interrupting the gas flow would have stopped providing customers[95]. Interestingly, arrogance was also an issue in that explosion, since "key information [were] not disseminated in a reliable manner" at a group level, having members form their own impression and even conflicting views[96]. Finally, reinventing the wheel also had an impact upon the explosion, as investigators underline that the "unnecessary overlap and duplication of their efforts" caused much difficulty in answering emergency phone calls and informing the technicians supposed to shut off the valves[97].

A last symptom to be observed is underwhelming: a leaving shift team orally briefs the incoming crew that replaces them instead of resorting to the information system, for instance. Also, tasks of surveillance are not clearly assigned during a shift: once together in the same room, the crew is supposed to oversee the whole transmission network and answer phone calls from any region of the field crossed by pipelines. No specific member is assigned to the task of answering the calls, which has field team calling the data-gathering center several times put in contact with several interlocutors[98]. This way of working creates redundancies, that could easily be avoided if the same information system was adopted by all the stakeholders. Last but not least, the first three responders who intervened on the site lacked qualifications to operate the main valves, which delayed the extinction[99] –this reinforces the idea of problematic knowledge management.

Conclusion

The study has not only demonstrated that the relation between IS-related issues and pipeline explosions does exist, but also that they even play a substantial role in the three main causes of these disasters. Beside highlighting the tremendous impact of improper informational, documentational or communicational strategies in this particular business, the present study has also provided interesting insights concerning the type of information issues to which it can be confronted. These are of course only based on three case studies, but they nevertheless put forth interesting insights for further studies.

At various degrees, the most frequent IS-related issue observed in the case studies are project-related issues –two case studies out of three. Knowledge Management concerns two out of the three case studies. Interestingly, Data Quality issues have only been found problematic in one case study out of the three, whereas it seems to be well under control in the other two examples: this being said, the San Bruno incident demonstrates how central proper data quality is to the pipeline business. Another interesting point is that, in some cases, the results might be overlapping –such as lack of curiosity and interaction failures, or the non-fulfillment of expectations and wrong data governance. Also, the study shows that no two operators are similarly affected by the same issue.

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janvier 2018

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