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1. Abstract

When engineering operates on a global scale, collaboration should be encouraged by removing language barriers. Requiring stakeholders to work in a language that is not one of habitual use is at best a compromise and at worst a costly source of unmanaged risk.

Established practice and the restrictions of the tools we use mean that many systems engineering activities require various stakeholders to capture written information in a single human language. At the same time it is almost inevitable that there will be project members who are not fully conversant in the single language chosen. Model-based approaches help reduce the burden of language difficulties, but descriptions continue to include a text component. In most projects, certain stakeholders will interact mainly via the written word.

There are many hidden costs associated with the lack of an integrated translation activity in an organisation's workflows. People working in a language that is not their mother tongue work more slowly, struggle with the nuances of linguistic choices, and make more errors. Where translation is part of the workflow, it often happens outside of the controlled engineering environment, introducing unknown and unmanaged risks.

Organisations will benefit by adopting a multilingual approach as an integral, quality-controlled part of their everyday workflows. “Left shifting” multilingual capability and translation effort to early phases of a lifecycle can reduce risk and increase quality. This paper proposes a flexible, multilingual engineering environment that allows stakeholders to create and access the same information, but in their language of choice. Examples are provided of how a multilingual approach can be incorporated alongside existing tools and practices. More advanced techniques that make multilingual information a fundamental part of systems engineering are also explored. Both traditional and model-based systems engineering environments are considered.

2. Categorisation

Accessibility Beginner

Application Research, Organisational Capability, Enterprise Systems Engineering, Project Management, Risk Management, Translation

Topic Pushing the boundaries of SE Practice

3. Introduction

Good communication is essential to successful engineering projects. It is the key to effective collaboration and important for avoiding mistakes. If we are to build and validate the right system, then all stakeholders must clearly express their needs and be supported by services that ensure other parties can understand exactly what they intended to communicate. To build the system right, the message conveyed in those needs must be transformed into a set of increasingly detailed descriptions and artefacts, so that design, implementation, and verification may proceed with minimum error.

As complexity increases, so does the challenge of building systems that meet everyone’s needs. Complexity may be a property of the technical system of interest (target system), the collection of organisations, people, facilities, and tools that creates it (enterprise system), or more likely both. Managing this complexity is difficult in any circumstances, but when enterprise systems incorporate partners who use different languages, or perhaps even variations of a common language, the essential good communication is even harder.

There are many types of artefact that can benefit from multilingual versions on international projects. These include, but are not limited to, requirements, glossaries, management plans, policies, procedures, contracts, requests for quotations, drawing labels, model element descriptions, user guides, scope statements, use cases, entity relationship diagrams, process diagrams, and installation and maintenance instructions.

In a globalised world, very few complex systems are built in environments where stakeholders all have equal ability in a single common language. Trains in the Middle East are built by German companies with French-speaking staff. Nuclear power stations are proposed in the UK that are designed by the French and funded by the Chinese. It is an easy assumption to think that "everybody speaks English" (or another lingua franca), but do they? And if they do, can they read and write it too? Maybe, but with what level of understanding? If they cannot fully understand a detailed specification with difficult technical terminology, what solution is in place to transform your carefully crafted text into a form that they can really use effectively? Is it a managed, controlled process with measurable risk that is appropriate to the importance of the information conveyed?

This paper explores these questions and posits that things work better if the translation activity is considered early as an essential part of the engineering process and given due weight. The contention is that this "left-shifted" approach reduces risk, saves time, and delivers higher value to the organisations involved. This can be achieved by ensuring that multilingual capability is fundamentally integrated into every element of the system, with translation services promoted to all and provided as a quality-managed service at the right quality level.

4. Scope

The examples considered here are all concerned with the written form. There is no doubt that the closely related field of interpreting (spoken translation) has an important role to play in international engineering activities. Interpreting may be formal (using a professional interpreter) or informal (using bilingual staff). The author is a translation expert, but not experienced with interpreting. Interpreting tends to be transitive in its nature, facilitating discussion rather than serving as a permanent record. It is envisaged that the approach proposed here could be adapted to the use of interpreting in a project, however this remains a matter for future study. The impact of cultural differences on understanding is another closely related topic that is worthy of in-depth consideration, but again beyond the scope here.

The author also recognises that there are marked differences between working in a close team and preparing written materials that will be shared more widely. The assumption here is that the written material will be read by an extended audience that does not have frequent (if any) personal contact with the author.

5. Problem definition

Most of us are familiar with amusing examples of poor translation; embarrassing mistakes even sometimes hit the headlines (pity the Welsh officials who put an out of office notice on a street sign[i]). Highly visible, public examples may be rare on engineering projects, but, as is widely accepted, it is the unknown problems that should be of most concern for systems engineers.

In an international engineering activity, with globally distributed teams and suppliers, it is almost inevitable that there will be project members who are not fully conversant in the single language chosen. To a lesser extent, issues also arise due to misunderstanding of a common language (e.g. British vs. American English). Anecdotal evidence and the author's experience strongly suggest that the value of multilingual artefacts to engineering projects is underestimated and that related issues are rarely tested or measured.

The following case study clearly demonstrates the serious cost and time impacts on a real-world project of both good and bad translation provision. There is little doubt that this is not an isolated case. The author would welcome access to additional documented evidence of measurable events (positive and negative) on engineering projects that are attributable directly to translation.

5.1. Case study – Permitting for a new-build factory in Russia

A Swedish client with project offices in Germany and Moscow embarked on a €100 million capital project to build a new factory on a brownfield site in Russia. They engaged a UK-based project management company with a Moscow office, and an Italian main contractor. Here we contrast the expensive outcome of poor translation provision by the main contractor with the positive impact of a well-managed process elsewhere.

A permit was needed from the Russian authorities for the factory's gas supply, as well as for the correct design and installation of gas infrastructure, the combustion process, the risk assessment, and safety within the factory. A full set of design documentation had to be submitted in Russian, in the prescribed format, to the Russian permitting authority, together with a description of measures taken to conform to all the Russian regulations.

The main contractor had one year to prepare and submit the necessary documentation to the client. This included awarding the sub-contract, creating the design, and placing orders for equipment to meet the critical path of the project (there was about three months' "slack"). The contractor did this work to the client's requirements, and submitted detailed work in English on time. However, the submission of the necessary permitting documentation in Russian was delayed until almost the latest possible day. When the documentation was submitted, the Russian translation included incorrect technical terms and passages that did not make clear sense when read. Moreover, the correct information had not been supplied because the Russian regulations had not been precisely translated at the start of the process, so the Italian engineers did not fully understand what they needed to supply. Instead, they relied on their knowledge of Italian standards, incorrectly assuming this would satisfy the Russian regulatory requirements.

The permitting authority refused to accept the documentation and the contractor was forced to engage a Russian engineering bureau employing experts in the field of permitting documentation and regulations. As well as correcting the documentation, they also realised that the original design could not meet Russian regulations due to bad assumptions.

Ultimately, the translation errors at both ends of the process delayed the factory start up by about two months, directly leading to €500,000 in lost sales. Work by the Russian bureau and additional permitting costs added an extra €170,000, and a liquidated damages claim ran to €270,000. So "saving money" on translation cost €940,000, or nearly 1% of the entire project budget.

By contrast, the project management company that was responsible for civil permitting nominated their Russian office to lead the work and instigated a quality-managed process. Requirements were prepared in English by the client. The client's requirements and the civil designers' drawings and specifications were professionally translated into Russian and checked by Russian or bilingual engineers. The lead staff working on documentation were all bilingual and familiar with both Russian and English technical language. Permitting documentation was prepared natively in Russian.

The project management company submitted all documentation on time, had all plans passed and permits granted without delay, and incurred no unexpected costs.

5.2. Problem causes

As is evident from the case study, an appropriate level of translation planning and provision (or lack thereof) can have a marked impact on the success of a project. Many of the issues highlighted stem from a lack of awareness among the stakeholders of the effects of their decisions relating to translation. It is also clear that although the project benefited from good management of translation processes in one area, a lack of similar control at downstream suppliers had huge negative impact. The effect of failing to provide engineers with a good translation highlights why it is necessary to consider translation early at all levels of a project in order to avoid expensive problems. As well as these project level effects, many small errors may occur through over-reliance on bilingual staff. People writing and reading in a second language are less able to recognise ambiguity introduced by factors such as word order and vocabulary choice. Writers who are used to conversing or reading in a second language are likely to overestimate their abilities when it comes to producing quality documentation.

Another factor that may discourage "left shift" of translation effort is the restrictions of tools. Even if tools provide a multilingual user interface, Help system, and user guides, it is often difficult to support multilingual content. For example, databases may not natively support multilingual versions of elements, or if they do then this feature may not be configured for use. A few tools are starting to support multilingual content natively in the Content Management Systems arena, but this is not widely adopted in systems engineering or office software.

It seems to be a comfortable assumption for many that a non-habitual user of a language can make full use of a source text in a foreign language that they have learnt to some degree. At the same time, there is a common instinct to mistrust a translation process because it might introduce errors. But in fact, in both cases a translation process is taking place: in the former case it is a mental process, in the latter it is a well-practised professional

service. It seems likely that relying on untrained skill will carry greater risk than using managed processes and professional translators.

5.3. Value

So why should an organisation “left-shift”, and perhaps increase their spending on, multilingual activity to make it fundamental to key project elements? Because it is ultimately cheaper, quicker, lower-risk, higher quality, and frees up engineering resource. However, as with many other aspects of the systems engineering activity, even if stakeholders have the required awareness, it may seem difficult to establish return-on-investment until something goes visibly wrong due to mistranslation. If an organisation is engaged in working internationally and prepared to record and analyse some simple metrics, then it is by no means impossible.

For example, a German client is a successful international software supplier in the IT services sector. They made a decision as an early-stage business to have German-speaking software developers write user guides in English. Eventually they determined that the quality was inadequate and requested revision of the guides by a native speaker. This work took approximately two thirds as long as an equivalent translation from German. The company also calculated that their staff took 50-100% longer writing in English than in German. Factoring in the cost of the developers’ and translators’ time, choosing to write in German and obtain a translation costs the same or less as writing in English and revising. Note also that with the translation option, the company obtains both German and English versions and avoids the opportunity cost of developers spending longer than necessary writing. Of course, the company now writes all their documentation in German and has it translated.

Focusing particularly on multilingual terminology in automotive product documentation, Schütz and Nübel's[ii] analysis showed the cost of detecting and correcting terminology errors during product data definition to be 100–200 times lower than in the document maintenance phase, making a strong case for "left shift" of terminology work. It is reasonable to infer that similar orders of magnitude apply to other industries too.

6. Approach

The approach advocated proposes that translation be considered a fundamental part of the engineering process. It should be treated as an overarching activity that can be embedded into activities at all levels of detail and across all lifecycle stages. Translation should be a risk-managed, quality-controlled service, accessible to all at the right level of quality. As such, systems engineers are well placed both to recognise the value and to oversee implementation of a new strategy.

The goal is to reduce risk and facilitate collaboration by removing language barriers. Instead of assuming a single language by default, multilingual should become the norm so stakeholders can create and consume the same information in whatever their language of habitual use. Of course, multilingual information may not be required in some areas, but provision should be made for the eventuality that the content needs translation later.

6.1. Established best practice

Established practice regarding translation varies greatly across and within industries. Generally, translation is approached at the document level and is a downstream activity taking place once work has been completed. This can be effective if well managed, but inevitably introduces a delay in the availability of information, which can cause problems. By contrast, early availability of multilingual information at element level (e.g. individual requirements, descriptions of model elements) can increase understanding and facilitate collaboration.

Another approach is to use controlled language, the most well-known of which is the AeroSpace and Defence Industries Association of Europe’s Simplified Technical English standard (ASD-STE100)[iii], which has been required in the aerospace industry since 1986. The reason for its development is that “Many readers have limited knowledge of English, and are easily confused by complex sentence structures and by the number of meanings and synonyms which English words can have. The key factor for the creation of a controlled and simplified form of English was essentially a request from the customers (i.e. the Airlines), of which 80% are not native English speakers, and their need of doing correct maintenance to guarantee the aircraft availability.”

In a well-managed, controlled environment, STE can be a useful part of the solution. Its avoidance of ambiguity has many benefits for engineers working in English-only environments too. However, the extended environments in which systems engineers work often cannot be as closely controlled as in the aerospace domain and it cannot be guaranteed that documentation users have the requisite English skills.

The two approaches can be combined, as illustrated by a European rail industry example. In 2004, the EuRoMain European Technical Documentation Network (ETDN)[iv] project set out to define standards for technical documentation, making it available wherever needed. As part of this work, constructors and operators wanted to improve availability of maintenance information in local languages for trains crossing borders. The intention was that ETDN not only serve up documentation that had a consistent structure, format, naming convention etc. anywhere in Europe, but also that it could do so in the language of choice of the maintainer. This had the potential to reduce delays if a train broke down, as it could take a long time to find a qualified local technician who could also read the foreign language well enough to follow repair instructions reliably.

With this approach, a version of each document is marked as the "master", with other versions then being translations of that. There was no requirement that all masters had to be in the same language (English, for example), meaning that manufacturer of a part etc. would write the "master" version of the document in the language of their choice. English master versions would be written in STE using a customised vocabulary and grammar. Even in the absence of controlled language for the target text, this would aid translation enormously, because translators would have much more precise knowledge of the source text meaning. To the knowledge of the author, the ETDN's standard has not been adopted, but it serves well as an example of a managed approach that extends beyond a single organisation.

6.2. Risks

A simplistic approach such as “everybody works in English” may have been used for many years, but this does not mean it was or remains the best option. It undoubtedly masks hidden risks and may be adding hidden costs. The reality is that people writing in a language that is not their mother tongue work more slowly, struggle with the nuances of linguistic choices, and make more errors. When reading, they are more likely to misinterpret meaning. Where translation is part of the workflow, it often happens outside of the controlled engineering environment. This introduces unknown and unmanaged risks, such as engineers relying on assumptions or using free automatic translation tools. Automatic translation may be suitable for low-risk situations, such as agreeing the time of a meeting, but it can rarely be relied on for technical work unless a heavily customised system is used. Free online services often release confidential information to unknown third parties.

Quantifying existing risk in existing processes in a project or organisation may be difficult because the risks are often unknown or unrecognised. However it should be possible to quantify translation-related costs and delays on existing programmes through a process that incorporates monitoring issues and recording language problems as a root cause. Analysis of the results should then give some indication of the scale of the issue and point towards effective remedies. Other risks that need to be considered are security of data processed by external agencies and use of consistent terminology, both of which also apply in monolingual activities.

Of course, choosing to translate content is not without risk, hence important documents are often accompanied by a statement such as “the source language version shall have precedence”. This approach does not really mitigate the overall risk, instead it just passes responsibility down the supply chain. The risk has to be absorbed and passed on as a cost by the supplier. A better approach would be to quantify the risk associated with translation (or lack of it) and control and manage it, as with other risks on a project. Sharing managed risk should ultimately lead to fewer issues and better relationships between stakeholders.

Mistranslation by inexperienced translators, including bilingual staff not sufficiently aware of the specialist areas of interest, is another concern. Specific data on the role of experience is hard to find, but Künzli[v] (2004) does offers a comparison of student translators vs. professionals: “Translators have to make decisions. An analysis of how they deal with uncertainty in connection with ambiguity lends itself to the study of risk-taking… The results show a higher propensity for risk-taking among the student group. Also, the [professional] translators mitigate potential risk by making the client a partner in the translation process.” It can be inferred from this study that ad hoc translation approaches (such as using bilingual staff with no translation training) also introduce similar risks.

There is a good body of work studying risk in translation, and this means it lends itself well to a quality-managed approach (unlike some monolingual solutions). Anthony Pym (2015)[vi] explores “How can a translator distribute effort in order to manage risk rationally when translating?” and proposes “If you are aware that not all text elements involve the same degree of communicative risk, you might rationally choose to work hard on the high-risk elements, quickly on the low-risk elements, and apply a sliding scale for the things in between.”

6.3. Translation quality

As Pym suggests, once communicative risk has been understood, it is possible to begin to control and manage quality. The Institute of Translation and Interpreting recommends seven levels of quality in its Recommended Model General Terms of Business for Commissioned Translation Work [vii]. Their approach is based on the level of human intervention, ranging from raw machine translation to checked-in-triplicate by experts.

Drugan[viii] (2013) posits that there are two different models of translation quality: top down (traditional controlled and managed) and bottom up (use feedback mechanisms to build up quality). In traditionally managed, safety-critical systems, the former approach is more likely to align with existing organisational processes, while the latter may map better to less formal, evolutionary approaches.

Whichever is used, it is important to introduce the right quality at the right project phase and to measure the success of the chosen strategy to allow improvement. In this case, improvement could even mean a reduction rather than an increase in quality. This may seem laborious, but the value derived can be maximised by taking a systems approach. It is a central tenet in systems engineering that investment in early-stage project activities ("left shift") will lead to savings later in the project. In his thesis on "Benefits of Adopting Systems Engineering Approaches in Rail Projects" Elliot (2014)[ix] argues that the benefits of applying systems engineering on projects will be enjoyed as a consequence of reducing unnecessary delay in deciding to make a change. Our contention here is that controlled and managed translation provision can contribute to reducing such delays.

Everyone involved in a development process, from suppliers, through requirements engineers, to the verification and validation teams should consider translation needs and be familiar with the processes involved in providing the right text, in the right language, at the right place and time. If translation services are implemented well, then this should relieve the burden on teams and allow them to concentrate on their area of expertise with confidence in the information that they and others are working from. As Elliott argues well, "The full benefits of applying systems engineering will only be enjoyed if other pre-requisites for sound decision making are in place".

7. Solutions

Solutions that facilitate the above approach aim to make translation an integral, quality-controlled part of everyday business processes. Both document-centric and model-based systems engineering environments can be addressed according to an organisation's needs. In both cases, the focus should be on "left-shift", that is translating early in small units with a view to aiding understanding without delay and maximising reuse of translation assets. These are not new ideas, but a combination of globalisation, increasing complexity, and outsourcing practices mean that the need to implement them is ever more pressing. Much can be achieved within the scope of existing enterprise systems without major disruption. There are also a number of active projects looking to increase the level of integration and automation in systems engineering environments.

In the field of requirements engineering, the author's company, Omflow Ltd., is actively developing a system to allow translation of a requirements management database using external tools. Using a standard output format (Requirements Interchange Format), the tool can take an export from almost any requirements management tool and package this for translation in an array of off-the-shelf translation environment tools. This gives a direct interface to translators and their familiar environment, where they can handle issues like reuse, consistency, and terminology management. Automatic translation can also be incorporated in the workflow if desired. Once text has been processed, it can be sent back to the requirements tool, either as a copy of the model or stored in the source model using dedicated translation fields, if available. Future developments will incorporate support for XML Metadata Interchange (XMI), translation quality levels, and workflow management.

Holt, Perry, and Brownsword[x] propose a Description pattern that supports integration of multilingual content as a fundamental concept in models for systems engineering. Their Systems Modelling Language (SysML) pattern aims to 'Support description of elements'. This includes 'Support localisation', meaning that the Pattern must allow extended textual descriptions of the element to be produced in a number of languages. The Element proposed is a meta-class for all model elements that need to have multilingual Element Descriptions. This means that all the ontological elements in an organisation's systems engineering ontology that have to be translated would be sub-types of Element (which might be renamed Translatable Element or similar). By adopting this meta-class globally in the model, all elements thus acquire the fundamental property to become

multilingual if required, without disrupting the design. A set of rules constrains the localisation of an 'Element' through zero or more 'Element Descriptions'.

Both these approaches seek to place the creation of translated content early in the engineering process and thereby facilitate the risk and cost reduction proposed in this paper.

8. Conclusions

The discipline of systems engineering advocates for tools and techniques that allow engineers to approach the ideal of a single source of truth for information in their projects. It is only by reducing duplication and managing versions and variants that we can hope to successfully develop the complex products and product lines that prevail today. To stay on time and on budget, we must implement strategies to control and manage risk.

Provision of (or lack of) multilingual content is an often underestimated source of risk, but one that can be well managed using existing tools and techniques. Ignoring the issues and insisting on monolingual content may help to preserve the single source of truth, but if that single source cannot be properly understood by the stakeholders it is intended to serve then its aim has not been achieved. Translation naturally introduces new risks and costs, but these can be managed as a quality-controlled process and in many cases are lower than the risks and costs of the monolingual alternative.

When working internationally it is best practice to have alternative language versions managed at source as part of a flexible, multilingual engineering environment. Treating translation as an add-on, downstream process may be effective in some circumstances, but generally the earlier translation is made available as a service, the better the engineering team is served.

“Left-shifted” translated content can be incorporated into both document-centric and model-based system engineering environments, and a number of existing and new techniques are available to support this. A planned multilingual approach gives project teams the international capability that they need to understand and express themselves clearly and to better manage errors, costs, and programmes anywhere in the world.

9. Contact

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