

ECONOMIC ASPECTS OF MACHINE TRANSLATION

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After a description of various marketable MT and MAT products and a review of some scenarios for the design of MT and MAT working stations, an analysis of the economic aspects of MT and MAT, as compared with human translation, is made :

- investments in systems and dictionaries (new developments and updating), and operating costs
- staff involved and time delay of service.

1. Introduction.

One usually associates the concept of the economic aspects of a marketable product with such notions as cost, investment, price, time delay, quality, demand, etc.

This is generally sufficient when one deals with a product which constitutes a specific example of a family already on the market: e.g. a new brand of coffee or the new model of a car.

When one has to consider an entirely new product, such as machine translation, one must first try to think about its potential uses:

- what kind of service might it render ?
- in which technical and organizational conditions could it be implemented ?

We tried to answer precisely these questions, among others, in a market study of translation which we completed a few weeks ago for the Commission of the European Communities (Van Slype et al.- 1981).

2. Marketable MT and MAT products (machine translation and machine aided translation).

Machine translation may, in fact, be a basis for three different kinds of product:

- rough translation of free text without further correction (i.e. without post-editing) : such translation may be most valuable to people wishing to get a rapid acquaintance with a journal article, a conference paper, or a working group paper, written in a language they do not understand, in the (numerous) cases where they cannot afford the cost and/or the time delay for a normal human translation process.

According to some indications, this potential market (very frequently and imperfectly satisfied nowadays by an oral translation made by a colleague, a family member or ... a translator) represents some 30% of the actual market for formal, written, human translation. The conditions for the realisation of this market are:

- . cost and time delay significantly reduced (e.g. one order of magnitude lower than human translation)
 - . average text intelligibility* of MT above 75% (versus 98 to 99% for source text)
 - . easy access to a MT system
- translation of free text, followed by careful correction (called post-editing) in order to reach the same quality (mainly intelligibility, fidelity, grammatical correctness) as human translation, this product concerns directly the market for human translation, where it brings the kind of job reassessment usually associated with a technological change; it permits the carrying out of the same volume of work with a reduced staff of translators, converted into post-editors (or a higher volume of translation with the same staff), at about the same cost as or a little bit less than human translation; but with considerable reduction in time delay. The conditions for the development of this machine-aided translation product are:
- . acceptability to the human translator, which appears negotiable when the quality of the MT system is such that the correction (i.e. post-editing) ratio is lower than 20% (1 correction every five words) and when the human translator can be associated with the upgrading of the MT system
 - . use of a word-processing subsystem, allowing easy input of the source text and low cost and fast output of the revised translation
 - . easy access to a MT system, with cost and time delay significantly lower than human translation
- translation of controlled text (i.e. pre-edited text, or text written with a limited vocabulary and a limited number of grammar rules), followed by careful post-editing; this product may be used by organizations producing their own texts, and thus able to impose from the start, writing rules that would allow the post-editing efforts to be minimized (e.g. instruction manuals, maintenance manuals, ...); the conditions for the development of such systems are :
- . control of the source texts
 - . access to a MT system with costing and time delay features as for the other MT or MAT products
 - . design of the controlled language subsystem and of the MT subsystem such that the correction ratio is brought to a low level (say : 5 to 10%), permitting a reduction not only in time delay (as with MAT of free text) but also in costs.

3. Design of the MT and MAT working station.

After this description of three marketable MT and MAT products, let us review how they could be implemented, i.e. how a MT/MAT working station would look.

* By intelligibility, I mean the subjective evaluation of the degree of clarity and comprehensibility; this evaluation is made for each sentence in its context, and is then averaged for the whole sample.

The first MT systems were batch processing ones: this means that you had first to keypunch your source text onto punched cards or magnetic tape; to feed an input device in the immediate surroundings of the computer with these cards or tape; and to wait (a few hours or a few days) for the willingness of the computer operator to load the translation programs and the dictionaries and to launch the processing. You then received, by mail, a print-out of the rough translation; you had to revise that print-out and to insert your corrections. The post-edited translation was then given to a typist for final typing.

This process was good enough for experimental trials and pilot operations, but was clearly not satisfactory for operational conditions (example: Systran I).

Nowadays, a MT or MAT system is linked to a word processing subsystem, which allows you :

- to have your source text automatically input to the computer
 - . either through a magnetic reading device, if the text is available in magnetic form (e.g. when the text was initially produced by a WP system, or by a photocomposing system, or when it is already stored in a computer to which you have access)
 - . or through an optical reader, if the source text is available in printed form and if the character font used is one of those that your OCR (optical character recognition) device can deal with
- or, if your input text is available only in handwritten form, or in stenographic form, or in sound recording form, to type it on the keyboard of a terminal linked to a MT computer facility
- to enter, on the same terminal, special meanings or specific terminology
- to obtain, on your terminal, either on a visual screen, or on paper, or on both, the rough translation
- to revise the rough translation
 - . either directly on the terminal, by typing the corrections yourself
 - . or first on paper, and then by having a typist keyboard your corrections on the terminal
- to receive the revised translation, printed at your terminal, with a typewritten quality, and in the same lay-out as that of the source text
- or to receive the revised translation, on a magnetic tape, ready for photocomposing, if the translation is to be typeset.

4. Business organization.

The minimal equipment required in an automated translation service is the terminal, used

- to input the source text, some complementary pieces of lexicon and the post-editing corrections
- and to output the rough translation and the revised translation.

We have seen that this equipment would be connected to a MT facility.

Now, as regards this MT facility, there are several kinds of organizational design to be envisaged:

- first, the MT facility may be located within the translation service; in that case, the MT facility consists of a minicomputer, totally dedicated to MT application. For instance, Weidner Communications Inc., in Utah, USA, markets a turnkey system, composed of:
 - . a Digital Equipment minicomputer
 - . a few terminals
 - . the MT software
 - . a minimal dictionary (+ 10,000 entries)
- second, the MT facility may be located within the translation service parent organization, in its computer centre; in that case, the computer will most generally not be dedicated to MT, but will run MT programs in conjunction with other programs, in a time-sharing mode. For instance, Systran Institute GmbH, in Stuttgart, markets a Systran software package, to be processed on your own computer, and including:
 - . the MT software
 - . a dictionary
- thirdly, the MT facility may be located in a specialized organization, called a MT host, to which your terminal would be connected through a public telecommunication network (leased line in the case of heavy traffic, switched line in the case of light traffic). For instance, the Commission of the European Communities envisages launching in the medium run (2 to 3 years), a MT service, based on a MT host computer, and available to all interested users of EURONET-DIANE. This system will allow users who have searched a bibliographic data base on DIANE, to have the abstracts found, written in English or French, automatically sent to the MT host, via Euronet, and to get a rough translation in, respectively, French or Italian, or English.

The two first organizational structures are open to any existing translation bureau or translation department, or to any newcomer in the profession; for instance CISI, the French Compagnie Internationale de Services en Informatique, has envisaged launching in Canada a translation service based on MT, with Systran II and human post-editing, but has finally given up its project, due to opposition from the Canadian government.

The latter organizational system is, for the moment, only designed for final users in a specific area (rough translation of bibliographic abstracts), but could be thought of, as ultimately a MT time-sharing service, open to any client.

Now that we have some ideas of the organization, the process and the final output of MT and MAT systems, we may go on to their actual economic aspects.

We shall first consider the cost aspects, then examine the time delay for the service, and finally conclude with some consideration of the staff involved.

4. Costs.

As for any product, we have to look at:

- investment costs
- operating costs.

4.1 Investment costs.

The investment costs of a MT or MAT system may include:

- hard: the necessary equipment
- soft: the translation programs
- dictionary: the lexicon(s) used by the translation programs.

4.11 Hardware.

The hardware includes:

- the cost of terminal equipment which, in every case, would be born by the translation service
- the computer,
 - which would be an investment for the translation service in the case of organizational structure n° 1 (dedicated facility)
 - whose costs would be charged to the translation service in proportion to its actual use (i.e. they are operating costs, and not investment costs) in the case of the two other organizational structures (internal or external time-sharing).

4.12 Software.

The acquisition of the MT software should be considered from two points of view:

- the initial investment of the risk taking initiator of a MT system, be it:
 - its private inventor, as in the case- of Prof. Peter Toma for the first developments of several Systran bilingual systems, and of Weidner Communications Inc., for the creation of various Weidner bilingual systems.
It is reported, for instance, that the Weidner system received, from the start, a research and development credit amounting to 5 million US dollars
 - its private vendor, as with the Systran Institute GmbH, for the development of the Systran German-English system
 - or a state or international sponsor, as is the French government, for the Grenoble MT system; the Foreign Technology Division of the American Air Force, for the Systran Russian-English system; and the European Commission, for the development of three versions of Systran (English-French, French-English, English-Italian) and for the creation of the future EUROTRA (every European community language).

The development costs of Systran in USA are estimated to be 5 million dollars in a twenty year period. The research and development budget of EUROTRA was settled at £7 million, to be shared between the Community and the Member States

- the investment by a translation service.

In any case, the ordinary translation service is quite unable to support such huge investments; when it acquires a MT system, or the right to use a MT system, it supports part of that investment through the payment of one or several of following charges:

- . initial payment (truly an investment)
- . fee per unit of time or per unit of use (actually an operating cost)
- . maintenance (an investment or an operating cost, according to bookkeeping habits; usually an operating cost).

These charges may cover either the software only, or, as already mentioned, the hard, the soft and a basic vocabulary.

For instance,

- Weidner Communications Inc. was quoting, in 1980, £130,000 for a turnkey system for one language pair, including :

- . a Digital Equipment minicomputer
- . four terminals
- . MT and WP (word processing) software
- . current dictionary (10,000 entries).

The same system, but with 20 terminals, costs £220,000. In addition, there is a price of £75,000 per supplementary language pair and 1% per month for maintenance.

- Systran Institute GmbH was offering, in 1980, a "Systran licence contract", including, for one language pair:

- . fixed cost for dictionary update (5,000 technical terms, by Systran Institute, 10,000 by the client), software adaptation (to implement the system on the client's computer), testing and training £22,000
- . annual licence fees £25,000
- . quantity licence fees
 - * first million words/year included in annual licence fees
 - * from 1 to 5 million words/year : £1.2 per 100 words
- . annual system maintenance £5,000.

4.13 Dictionary.

The dictionary is a very important item when investing in a MT system. It appears that, in many cases, the volume of the specialized terminology used for a given final patron greatly exceeds the size of the standard vocabulary, whose initial building costs may be shared between many users.

For instance:

- the English-French standard vocabulary delivered by Prof. Toma to the Commission was found to be almost entirely useless for the Commission environment

- Weidner supplies a very short standard dictionary (a few thousand terms) with its turnkey systems
- the specific dictionary of Systran Russian-English for the American Air Force includes more than one million entries; the specific dictionary of Systran English-French of the European Commission numbers more than hundred thousand entries in the fields of food and agriculture, science, technology and administration.

Our own evaluation of the English-French Systran, in 1976, showed that one average entry in the dictionary of that system:

- requires 15 minutes (terminological research, linguistic coding and data capture)
- costs £3.2 (manpower and computing time) (£1 = 75 BF).

The Systran Institute GmbH quotes, in 1980, £0.7 per entry in the technical dictionary, based on text submitted by the client.

The cost of the vocabulary seems to be a very important feature of a MT system; a high level of technical sophistication of a MT system may improve the quality of translation, but may also lead to impossibly high costs: the Canadian TAUM-Aviation system was rejected by an evaluation team, among other reasons, because of too high a cost for the building of dictionaries: 3 h 45 and £23 per entry !

4.2 Operating costs.

The operating costs of MT and MAT include direct costs and indirect costs.

4.21 Direct costs.

The direct costs include three main items:

- work on the terminal
- MT processing on the computer
- human post-editing (in MAT).

4.211 Terminal processing.

The terminal processing may include:

- input of source texts (MT and MAT)
- input of new vocabulary (MT and possibly MAT)
- output of rough translation (MT and MAT)
- input of post-editing corrections (MAT)
- output of post-edited translation (MAT).

The cost of input of the source text may vary from a maximum when a manual keyboarding has to be done, to a minimum when optical character recognition is available and possible, or, even more so, when the text is already available in magnetic form. The latter case is likely become more general in the future, as both the author of the original text and the translation service will have their documents typed on word processing equipment (for in-house data) and as more and more books and journal articles are photocomposed, and these are made available, as a by-product, in electronic form.

NB: the saving in input cost, when the text is available on machine readable form, is partly cancelled out by some more computer processing (text reformatting).

In order to compute the terminal processing cost and to charge it to the correct input and output jobs, one must:

- compute the cost of the terminal(s), e.g. per annum (rental, or depreciation plus maintenance)
- compute the salary plus employer charges of the operator(s)
- cumulate both costs, and divide the total amount by the total number of hours worked each year by all the terminals : this will give the hourly rate for a terminal
- estimate, through observations, and/or sampling, the fraction of time devoted on all terminals to each of the five above mentioned jobs
- apply these fractions to the cumulated costs of equipment and personnel: to obtain the amounts to be charged to each job
- divide the three first amounts by the number of hundreds of words translated (with and without post-editing) to obtain the unit costs of:
 - . input of source text
 - . adjustment of vocabulary
 - . output of rough translation
- divide the two last amounts by the number of hundreds of words translated and post-edited, to obtain the unit costs for:
 - . input of corrections
 - . output of post-edited translations.

4.212 MT computer processing.

Computer processing is usually invoiced to in-house users as well as to outside organizations according to rather intricate formulae, taking into account resources used (central processing unit time, number of input-output operations, storage volume, ...); these formulae are very easy for computer people to manipulate, but have the very bad characteristic that they cannot be checked by the users ! So it is better to try and negotiate with the computer department a unit price on some traceable output, e.g. per 100 translated words, or better per 100 source words. In these cases, some attention must nevertheless be paid to the fact that in most MT systems, individual punctuation marks are counted as full words; if one is to compare the cost of MT with that of human translation, where tariffs are usually based on 100 (actual) words or on text lines, some adjustments are required.

When the computer is dedicated to MT, then the processing cost is easier to compute: divide the total computer costs (annual rental - computer maintenance usually included - or depreciation, plus maintenance; salary of computer operator, if any - many minicomputers are operated by their users), by the number of hundreds of source words submitted to MT during the same period.

4.213 Human post-editing (in MAT)

The salary of the post-editor(s) (employer's charges included) is divided by the number of hundreds of source words submitted to MT and to human post-editing during the same period. If the post-editors are at the same time operators of the terminals for input of source text, input of new vocabulary, and/or input of post-editing corrections, their costs are only counted once:

- as operators for the two first kinds of input
- as post-editors for the third kind of input.

4.22 Indirect costs.

Indirect costs normally include:

- depreciation of the investments
- overheads.

4.221 Depreciation of the investments.

We have already taken into account the depreciation (or the rental) of the hardware in the operating costs, because:

- a normal computer processing cost, charged in-house or by a subcontractor, includes that depreciation
- terminal equipment in a translation service is normally dedicated to translation, and may thus be directly amortized on that activity.

The investments to be considered here are:

- MT software acquisition
- vocabulary building.

These investments may be depreciated according to the usual rules,

- over a five year period
- on a linear, progressive or decreasing method.

When part or all of these investments are paid through an annual and/or volume licence fee, the value of the depreciation is of course replaced by that of the licence fee.

4.222 Overheads.

Overheads (managerial staff, office space, ...) are of course to be taken into account when computing the cost of translation.

However, as the overheads are about the same in MT or HT, one does not usually take them into consideration when comparing the two kinds of translation.

4.3 Examples.

Our own evaluation at the European Commission, in 1976, of the Systran English-French MAT system, compared with HT, gave the following results (cost per 100 words of source text, software investment cost not included).

Activities	Human translation		Machine or machine-aided translation	
	In a public institution	By a private translation bureau	In a public institution	By a private translation bureau
Data capture	-	-	£ 1.20	£ 0.67
Translation	£ 5.60	£ 2.67	£ 0.40	£ 0.40
Typing	£ 0.47	(includ.)	(includ.)	(includ.)
TOTAL without post-editing	£ 6.07	£ 2.67	£ 1.60	£ 1.07
Correction (revision or post-editing)	£ 2.00	-	£ 4.00	£ 1.33
Typing	£ 0.47	-	£ 0.47	(includ.)
TOTAL with post-editing	£ 8.54	£ 2.67	£ 6.07	£ 2.40

An evaluation of the TAUM-Aviation project, in Canada in 1980, gave comparable results, except for the cost of MT processing, which appeared very high - another reason for the rejection of the system. (Cost per 100 words, software investment cost not included) (Gervais - 1980).

Activities	Human translation	Machine translation
Data capture	-	£ 0.68
Translation	£ 4.67	£ 3.58
Correction	£ 1.42	£ 3.41
Typing	£ 0.68	£ 0.85
TOTAL	£ 6.77	£ 8.52

WTCC (World Translation Company of Canada), the company which developed Systran II and which markets it in Canada, published in 1980 a cost comparison of HT and MAT (WTCC - 1980); on the basis of:

- 1 million words to be translated per year

- 1,666 words/day/human translator

- 5,000 words/day/post-editor

HT costs £10.2 per 100 words

MAT costs £5.3 per 100 words (including data capture, computer processing, but not depreciation of software and dictionary).

Systran Institute GmbH estimates, that in 1980, on the basis of

- 1 million words/year

- 1,800 words/day/translator

- 5,400 words/day/post-editor

HT costs £5.9 per 100 words

MAT costs £2.1 per 100 words (software and dictionary depreciation not included; data capture not included).

4.4 Break-even point and pay back period.

4.41 Formulae.

In order to compute the limit of profitability of a MT or MAT system, one should establish the number of words necessary to be translated, to write off investment costs.

A rough formula would be:

$$N = \frac{I}{C_H - C_M}$$

where:

N = minimum number of words necessary to be translated for financial advantage to be taken of the investment

I = investment

C_H = cost of human translation, per word

C_M = cost of machine translation, per word.

Now if a given translation service has N words to translate per annum in a given language pair, the investment is paid off within one year, and the formula is correct.

But if the activity is less than N, the investment will become profitable only after two or several years, and one should take into account the interest rate on the capital invested; the formula becomes more intricate

$$I = \sum_{t=1}^x \frac{n (C_H - C_M)}{(1 + i)^t}$$

where :

I = investment

n = number of words to be translated per annum

C_H = HT cost per word

C_M = MT or MAT cost per word

i = financial market interest rate

x = pay back period = value of t (number of years) for which the actualized profit equals the initial investment.

4.42 Example.

Taking into account our estimates for Systran costs at the European Commission, we have:

- revised human translation in a public institution : £0.0854 per word

- post-edited machine translation in the same institution :
£0.0607 per word

- investment cost to the Commission for the Systran E-F software and for an E-F dictionary in the field of food and agriculture :
£187,000

- break-even point:

$$\frac{187,000}{0.0854 - 0.0607} = 7,570,000 \text{ words}$$

- as the Commission does not have such a volume of translation in that language pair and in that field, the other formula to apply (supposing n = 1,900,000 words/year and i = 10%), is:

$$\begin{aligned} 187,000 &= \sum_{t=1}^x \frac{1,900,000 (0.0854 - 0.0607)}{(1 + 0.10)^t} \\ &= \sum_{t=1}^x \frac{46,930}{1.1^t} \end{aligned}$$

If t = 4, we have

$$\begin{aligned} 187,000 &= 46,930 \left(\frac{1}{1.1} + \frac{1}{1.1^2} + \frac{1}{1.1^3} + \frac{1}{1.1^4} \right) ? \\ &= 46,930 (0.9091 + 0.8264 + 0.7513 + 0.683) \\ &= 46,930 \times 3.1698 ? \\ &> 148,758 \end{aligned}$$

Thus, four years are not sufficient to write off the initial investment.

If $t = 5$

$$187,000 = 46,930 \times 3 - 7907 ?$$
$$> 177,898$$

If $t = 6$

$$187,000 = 46,930 \times 4.3552 ?$$
$$< 204,390.$$

Thus, the pay back period is between five and six years.

5. Time delay.

One main advantage of MT is that it permits a considerable decrease in the time delay between a translation request and the delivery of the translation.

The actual gain arises from several elements:

- the form of the source text and data capture equipment available: the keyboarding time delay will be:
 - . zero or nearly zero if the source text is in magnetic form and may be input as such to the computer
 - . a few hours if the source text is in typed or printed form and if one has adequate OCR equipment
 - . a few hours to a few days, or even weeks, if the text has to be manually keyboarded
- the organization mode of computer processing:
 - . in batch mode, the translation processing delay may be counted in hours or days
 - . in interactive mode, the delay can be expressed in minutes or hours
 - . without word processing, the final revised document has to be wholly typed again, if a perfect machine copy is necessary, and this may require supplementary hours or days
 - . with word processing, only the corrections have to be typed, and the final typing is carried out automatically, within a few minutes or hours
- the kind of translation product required :
 - . zero supplementary post-editing time delay for rough translation
 - . short post-editing for pre-edited text
 - . longer post-editing for free text needing careful revision.

Because all these elements are closely connected, it is difficult to define a typical MT and MAT time delay, to be compared with a typical HT time delay. Nevertheless, experience so far shows significant decrease in delay.

6. Translator staff.

Will MT and MAT decrease the number of translators in the medium or long term?

This question is rather difficult to answer. Several points must indeed be taken into account:

- the elasticity of the demand to price fluctuations:
 - . an elastic demand is one which increases considerably in response to a price decrease, and vice-versa (e.g.: computer)
 - . an inelastic demand is one which remains steady, even when prices go up and down (e.g.: bread)
 - . in the case of translation, the actual demand is growing at a very fast rate (approximately 10% per annum) and a potential market (approximately 30% of the actual one) is waiting for a substantial price decrease before it becomes overt; demand for translation thus appears elastic towards a better processing effectiveness
- the existence of a substitute product, better fitted to market needs
 - . the consumption of bread, for example, is considerably reduced when a rising standard of living allows most people to afford better liked foods, such as meat, vegetables and fruits
 - . substitutes for translation are either no interlanguage communication at all (a solution which appears impossible in the prevailing economic, political, cultural and technical environment) or better language competence (a solution which appears limited, in spite of all language training); thus, in the medium and long term, translation does not have serious competitors
- the effects, direct and indirect, on employment, of technological progress and better productivity
 - . an improvement in productivity is usually associated, in the short term, with a lowering in employment; but, in the medium and long term, this effect may be compensated for by an increase in consumption, and thus may be overcome by an increase in employment, if demand is sufficiently elastic. For instance, there are considerably more people employed now in the computer industry, than ten years ago, because computers are much cheaper now, and thus much more in demand. A huge rise in productivity, on the other hand, in a saturated market, leads to unemployment (as is the case at the present time in the motor industry).

As far as translation is concerned, it appears that:

- the market is far from saturated
- the demand is ready to react positively to an improvement in price and/or time delay
- no substitute would replace the demand for translation.

In conclusion, it does not seem that the important increase in productivity brought about by MT and MAT should create unemployment among translators.

7. Bibliography.

GERVAIS (A.) et DG de la Planification, de l'Evaluation et de la Vérification.- Rapport final d'évaluation du système pilote de traduction automatique TAUM-Aviation.- Canada, Secrétariat d'Etat, juin 1980, 152 + 12 p.

Systran Institute.- Offer, Systran licence contract.- Munich, Systran Institute GmbH, July 1980, 16 p.

VAN SLYPE (G.), GUINET (J.F.), SEITZ (F.) and BENEJAM (E.).- Etude prospective du marché de la traduction: mieux traduire pour mieux communiquer; synthèse générale.- Luxembourg, CCE, août 1981, 124 p., rapport

WTCC.- The corporate and economic advantages of Systran II.- Ottawa, WTCC, 1980, 2 p., leaflet