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Economic Framework
for
Information Systems

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Contents

ABSTRACT

The following economic issues are discussed:
(i) the market mechanism in general and for the products "information" and "computers" in particular; (ii) charging computer jobs and pricing for the allocation of computer resources; (iii) investment analysis for data processing projects including the estimation of cash flows (objective and subjective probabilities), risk analysis (Monte Carlo simulation) and sensitivity analysis (based on statistical techniques).
43 References for further study are included.

1. INTRODUCTION

In this paper we discuss a number of issues within a single framework. The framework is provided by the theory of economics. The issues are (i) the laws which determine the supply and demand for information and computers within the company and on the external market place; (ii) the charging and pricing of computer jobs; (iii) investment analysis including risk (Monte Carlo) analysis and sensitivity studies.

In section 2 we survey some economic concepts needed in the following sections: oligopolistic markets, diseconomies of scale, the fixed cost problem, clerical cost displacement versus revenue generation. In section 3 we discuss the limitations of the market mechanism in general (no perfect competition, etc.) and for some products (such as information) in particular (public goods, externalities). We explain why benefit evaluation for information systems cannot be solved by the "internal market" mechanism (supply and demand within the company). In section 4 we examine cost charging and price setting, applying some of the preceding concepts (externalities, etc.). In section 5 we discuss investment analysis for data processing projects , including the prediction of future cash flows (objective and subjective probabilities), risk analysis through Monte Carlo sampling, and sensitivity analysis (including metamodels and experimental design). 43 References for further study are included.

2. THE MARKET MECHANISM

In economic theory the market with its price mechanism plays a crucial role. The way supply and demand interact depends on the characteristics of the market, the extremes being perfect competition and monopoly. In real life pure monopolies do not exist, since partial substitutes are always available: coal can replace oil for heating purposes, margarine is a substitute for butter, etc. The supplier may try to reduce this substitutability, by creating a technically unique product, such as a supercomputer for large scale metereological computations. What really matters, however, is not the technical qualities of the product, but the degree to which the consumer (user) differentiates among products. A well-known method to create an economically unique product is the creation of brand names: product differation. As Brock (1975, p. 47) points out, substantial brand loyalty does exist in computer selection practice. In general, oligopolistic markets are characterized by the presence of a few suppliers. The number of competitors may be limited by product differentiation. For highly technological products like computers, the entrance of new suppliers is further limited by the large amounts of capital required for research and production. The modeling of oligopolistic markets is quite difficult, and will not be pursued in this paper. (Kleijnen, 1979 b, does cover a situation with an oligopolistic market, using an IBM business game to model this system .)

Within a company certain supply and demand relationships exist among the various departments. If the company were organized on a pure profit center basis then the departments would be completely independent, i.e., they would be separate economic "households". In that case the classical economic laws could be applied straightforwardly. Actually the departments operate under a more or less restrictive corporate organizational policy. This policy usually provides the data processing (DP) department with a monopoly since the user departments are not permitted to buy services outside the company, a so-called captive market. The regular (complicated) monopoly theory, however, cannot be applied directly, since the supplier (DP department) and his customers (user departments) have a common ultimate goal, namely the organization's prosperity. We shall return to this issue later on.

Observe that whereas classical economics emphasizes the function of the price mechanism, Keynesian economics stresses the role played by income. Hence classical economics explains, say, consumption by its price relative to the price for competitive usage of income (i.e. savings), whereas Keynesian economics explains consumption as a function of available income; see also section 4 on pricing computer jobs.

The price paid for computers depends on the supply function for computers (besides the demand function). This function is influenced by technological progress - such as the introduction of LSI technology - and economies of scale, known in the computer field as Grosch's Law.[1)] Diseconomies of scale also exists: [2)] A large computer system usually needs data transmission facilities for its utilization, i.e., it needs terminals, modems, lines, teleprocessing software, etc. Moreover one larger system offers less protection against a break-down of the system than several parallel smaller systems. Users may further prefer their "own little pet system". Computer software as opposed to hardware, is most certainly suspect of diseconomies of scale. The production of major software products such as an operating system, requires so many programmers that management of the total effort becomes a serious problem; Brooks (1974).

For small production volumes, it is economical to utilize a production technique with relatively low fixed costs, say machine costs, and relatively high variable costs, say labor costs. Hence small information systems may not be computerized, because high fixed costs require massive production volumes. Note that software utilization has hardly any variable costs, but does have high fixed development costs; a centralized computer system may spread these software costs over many users. Mini-computers have reduced the fixed hardware costs, so that decentralization may become economically feasible. Software costs can also be spread over many users by using standardized software packages instead of custom-made software: buy-or-make decision [3]. A dynamic dimension of the fixed costs issue is the life expectancy of a production unit: the costs of a computer system can be spread over more users - as seen over time - by making the system more flexible, so that it can be used longer. Such flexibility is improved by modular software, higher level languages, emulation.

Kleijnen (1979b) further discusses some additional factors: division of labor, production integration, learning curve, etc.

The buyer of a computer system purchases a production factor. This production factor can be used to increase revenues (gross sales) or to decrease production costs by production-factor substitution. Clerical cost displacement corresponds with production cost reduction, realized by substituting capital for labor. Examples of capital-labor substitution within a computer system are provided by the increased use of high level languages which take less programming time (labor) and more computation and running time, besides additional memory space (capital). Such substitution is stimulated by rising labor costs. A different example is the computerized generation not only of some program, but of a complete information system; see the ISDOS project [4]. Observe that in practice substitution of capital (computers) for labor is intrinsically connected with technological progress, while the production volume is not necessarily kept constant. In the past post-war period of computerization, most firms experienced a growing demand for their products. This is one reason why computerization is not necessarily accompanied by growing unemployment [5].

The alternative reason for buying production factors is to increase (gross) revenues. Computers - or better computerized information systems - can improve decision making so that revenues increase. For instance, real-time airline reservation systems stimulate the sales of airline seats. Improved decision-making, especially at the operational level, may also decrease costs. For instance, the same customer service (output volume) can be provided with smaller inventories resulting in lower inventory carrying costs. Such a cost decrease is not a simple capital-labor subsitution, but implies technological progress. The optimum degree of computerization occurs when marginal revenues equal marginal costs [6]. However, the value (revenues) of a computer system - or more generally an information system - cannot be measured directly as there is no separate market where its output is sold. Exceptions are companies, such as time-sharing bureaus, that offer as their final product computer services [7].

3. LIMITATIONS OF THE MARKET

The classical economic model assumes perfect competition with many supply and demand parties and a homogeneous product, so that the "free forces" of demand and supply generate an equilibrium price. Supply and demand parties act purely rationally (homo economicus) with perfect knowledge: no uncertainties. The market mechanism acts as an "invisible hand" that ensures optimum welfare for the economy as a whole. For example, in the long run the market mechanism will eliminate inefficient suppliers. In practice many of the assumptions of the classical model do not hold: Suppliers differentiate their products (brand names), the limited number of suppliers may collude, inefficient production units may be supported by other divisions of a company, new suppliers cannot enter the market because of high research and development expenses, consumers buy only locally, payoffs are uncertain, decision-makers do not maximize but satisfice, etc. These factors cause the market not to function optimally.

For some products there are additional causes that make the market inadequate. The product may not be marketable in separate units: public goods. Examples are national defense, natural scenery, highways. These products cannot be sold in units to individual consumers. The consumption by one individual does not necessarily mean that other consumers have less. Products may further have external effects or spillovers, i.e. they have unintended effects on other producers or consumers. These effects can be negative, for instance, ecological pollution by a steel plant, health risk created by nuclear plants, waiting caused by other customers in a queuing system. Negative external effects are usually not reflected in the producer's costs. (This situation is changing: oil refineries are being charged for their damage to the natural sky-line.) The external effects can be positive too. For instance, investments may be stimulated by the possibility of buying certain products, say railway transportation service: economic infrastructure. Production of articles with positive spillovers may be stimulated by subsidies (negative taxes) [8]. A product may further have value both as a consumption good and as an investment: educational systems, library services. In modern economics, goods for which the market mechanism is inadequate, are evaluated using cost/benefit analysis. Some of its techniques, such as Net Present Value, are borrowed from other areas and will be discussed below. As a whole, however, the cost/ benefit approach does not seem to contribute much to the analysis of the benefits of computerized information systems. Therefore we shall not discuss this approach in more detail, but refer to the literature [9].

Obviously the product information suffers from many of the complications mentioned above: There is no unit of information. (The unit "bit" developed in the Shannon-Weaver "information" theory - a more accurate term would be"communication"theory - is irrelevant since we are interested in the meaning of information. Hence two messages of the same length, may have quite different importance: "your match burns" versus "your house burns" or "dog bites man" versus "man bites dog".) Hence the producer cannot supply the consumer with a specific amount of information. He does not even know how much information is contained in, say, the report he supplies since it depends on the receiver's prior knowledge. The reading of the report by other consumers does not reduce the information content for the original consumer (public good). It may, however, affect the economic benefits of that information: inside information has different effects in, say the stock market, when it becomes public information. So the competitive advantage is affected by the number of people using the information. Negative external effects of information production may be security and privacy risks. Positive external effects of information systems are clear since such systems form part of the necessary infrastructure. Information does not only serve decision-making, but may also be appreciated as such, i.e., be "consumed" [10].

The product computers does not show the problems just discussed for the product "information". It is a product well comparable to many other products, i.e., capital goods. As with such goods the market mechanisme does not work exactly as the classical economic theory assumes.

Actually, no industry shows such domination by a single suppliers, IBM. The industry is further characterized by product differentiation. New suppliers cannot enter the market because of tremendous research expenses involved, and old suppliers are eliminated because of this factor. Consumers cannot always shop around since they are "locked in" with a specific computer manufacturer because of conversion problems. So the market mechanism does certainly not function optimally. Note that besides the market for computers, there are also markets for the product "information". That information product can be, say, library services. We may also include software houses, consulting companies, and the like [11).]

Next we look at the market within the firm where suppliers and users of information meet. Some authors feel that they can solve the problem of benefit evaluation for information systems, by referring to the market mechanism [12)]. They emphasize that the data processing department sells a product to the other departments (users) on the "market place" within the company. This approach has serious limitations:

(i) The product is ill defined: lack of a unit of measurement, non-destructive usage, competitive benefits, negative external effects on security and privacy, positive external effects through the economic infrastructure, and consumptive versus productive usage. More specifically, the DP department offers an ambiguous product, namely DP-services and data. The services may be interactive computing facilities to which the user can subscribe. The data may be weekly reports, or a data base that can be queried interactively. Nevertheless, in principle we can still determine the production costs for each individual type of service and product; the cost accounting problems involved will be discussed in the next section. Another issue is that the user is often a supplier of the raw materials (data) on which the DP-department works. For instance, the inventory manager supplies weekly sales data whereupon the DP-department computes forecasts and order proposals. Such a consumer/producer relationship is rather unique in modern industry. (It is not unusual in handicraft: house-painters, tailors.) It means that the supplier does not offer a product, but offers a (transformation) service. This also affects his market situation. For instance, production can be done only on order; staple production is impossible.

(ii) The market mechanism works correctly only if the company is organized according to the profit center principle: The market mechanism is supposed to bring together producers and consumers. In a free-competition model there are a great many suppliers who are not colluding. In our case, however, there is a single DP-department so that a monopoly situation exists. The monopoly model does not pretend to lead to maximum welfare for the economy as a whole, i.e., the total company [13]. The company may decide to permit the users to go outside the company for their data processing needs. In that case a user may buy, say, number-crunching services from a time-sharing bureau. Usually, however, the company prefers to have most of its DP in-house. This preference is based on security and privacy protection, increased flexibility (control over rush jobs, informal procedures), and so on. The preference for in-house DP is not surprising since DP - computerized or not - is an essential part of the production process: Any production process needs management as a basic production factor (besides labor, capital, and land), based on information which in turn requires data processing. Besides the monopolistic position of the DP-department, the market mechanism is drastically affected by the common goal of the DP supplier and his customers. In a classic model the two market parties have conflicting objectives. In the present situation, however, both parties are members of the same organization that has an ultimate goal (or multiple goals) to which the parties agreed to cooperate. Only if the departments were pure profit centers, they would strive towards their own goals without regard for the overall goal. Such a construction, however, could mean the disintegration of the organization. It can be shown that, if the DP-department maximizes its own profit, then a suboptimum for the organization as a whole results [14].

Note that modern systems with distributed computing and networks of computers, complicate the above picture. The DP department becomes decentralized into geographical subdivisions. (Logically local mini's are part of the DP department, though organizationally they may be managed by the local user department.) The user may then choose between local and remote computing services. Nevertheless, if the DP department serves a single firm, its components are supposed to have a common, ultimate goal.[15]

How should the DP-price be determined, more practically speaking? Under a pure profit-center approach, the users could be charged at the external market price. However, if we wish to see the market as a mechanism for determining the benefits of information, then the price should depend on the supply function of the producer (DP-department and possibly, external suppliers) and the demand functions of the buyers (user departments). Hence, one factor is the costs of the DP-department, which include part of the company's overhead costs such as top management salaries and heating, allocated in a rather arbitrary way; see the next section. The other factor should be the benefits (value) to the user-departments. But <u>how</u> can these benefits be computed? The original problem has returned again! So the pricing of computer services within a company is not the answer to the problem of evaluating benefits to the company [16]. In practice, pricing computer services do occur. However, such a practice is a cost accounting issue to be discussed next.

4. CHARGING AND PRICING COMPUTER JOBS

In general, cost accounting is needed to compute the profit, i.e., to determine how well the company as a whole is doing "recently", say, over the past year or quarter. Therefore we have to use costs instead of expenses, and distribute fixed costs among product units over time (depreciation). Nominal profits have to be avoided using replacement (current) cost rather than historical costs. The resulting overall picture should be differentiated - allocating overhead costs - by product line and department, so that products yielding losses can be discontinued and inefficient departments can be concentrated on: management by exception. Therefore we further need concepts like joint costs (two products simultaneously produced) and cost versus loss. Standard cost per unit, multiplied by standard or expected capacity utilization results in a budget for the department or product line (or more precisely for the "cost center"; such a cost center may be "data entry"). Comparing budget estimates to actual costs is the area of variance analysis.[17]

Costs are also needed as a basis for pricing. Theoretically, profit maximalization requires that prices be set such that marginal costs equal marginal revenues. In practice a mark-up approach is often followed, i.e., the price is set equal to, say, 110% of the average cost. Such a policy is certainly reasonable for non-profit organizations such as hospitals.

Let us next concentrate on cost accounting, specifically in the computer area. Calculating the "exact" cost becomes difficult in the presence of fixed and joint costs.[18] Unfortunately, most computer costs are fixed indeed: CPU rent, software development costs, etc. Few costs are variable: input/output costs such as punched cards and paper, and the like. Joint costs are abundant too: The operating system and the data base system support many applications. In general, modern computer systems are characterized by "shared" resources. Recently guidelines for computer cost accounting were developed by a group of practitioners; Statland (1977).

Notwithstanding the problems of calculating the "exact" cost, computer charging is recommended, so that the efficiency of user departments, projects, product lines, and the DP department itself can be measured and hence be controlled. Moreover, if computer capacity is limited - especially during peak periods - this capacity must be allocated somehow (see also below). One solution is to have users buy computer resources from their budget, possibly charging a higher price at peak hours. Alternatives are: assign each user a fixed numer of CPU time units, utilize a first-come-first-served rule, and so on. A general discussion - not limited to computers - on the price mechanism for the allocation of scarce resources, including price discrimination and quantity discounts, price versus cost, and so on, can be found in Sharpe (1969). Note that "hard" budgets can be spent on either computer or other goods; "soft" budgets imply "funny" money spendable on computer services only.[19]

We assume that the reader is familiar with algorithms for charging computer costs, involving issues such as reproducibility, demurrage (spillovers), equitability, etc.[20]

Cost accounting and pricing are related, but definitely not identical. If the DP department were a pure profit center, it might maximize its own profit, guided by the law of equalizing marginal costs and revenues. If the department uses a mark-up policy, its goal may be cost recovery plus a "modest" profit. For the organization as a whole, pricing can serve as an allocation mechanism for scarce resources. Hence in peak hours higher prices may be charged; in the early phase of a new computer system low prices may stimulate usage. The reactions of the users to these prices, depend on their demand curves (value functions)and on the prices for alternative production techniques, i.e. manual methods or outside DP services: direct and indirect elasticities. As in a national economy, top management may amend the price mechanism by imposing maximum price limits, subsidizing certain users, etc. The reason for such intervention is, that the price mechanism does not work as perfectly as classical economic theory assumes. For instance, a user may have very valuable applications in mind, but may not have the income (budget) to pay the price. External effects (spillovers) may be compensated by taxes and subsidies (negative taxes). For instance, pioneering applications may be subsidi zed whereas peak-load usage which creates congestions can be charged extra.[21)] Other imperfections of the price mechanisme in general, and for information in particular, were discussed in the preceding section.

In summary, in data processing cost accounting is needed by the DP department, the user departments, and top management. The DP department and the user departments need such information for their individual cost/effectiveness evaluation. Top management needs this information in order to weigh DP investments against competing activities.[22)]

5. INVESTMENT, RISK AND SENSITIVITY ANALYSIS

Buying a computer or initiating a DP project, is an investment, i.e., money is paid now whereas revenues will materialize only later. Hence the classical problems of investment analysis or capital budgeting arise, namely the time value and the risk of future streams of expenses and revenues. Different time patterns of cash flows - affected by the system life cycle - may be evaluated through such familiar techniques as payback period, internal rate of return, or net present value (NPV) [23).].

In the computer literature some authors [24)] favor <u>the relative NPV</u>: Let PC denote positive cash flows or revenues, and NC negative cash flows or expenses. Then the relative NPV is defined as:

$$RNPV= \{ \sum_{t=0}^{n} PC_t/(1+p)^t\} /\{ \sum_{t=0}^{n} NC_t/(1+p)^t\}$$

Their idea is that if two projects have the same NPV, but project 1 requires a payment of, say 10 K dollars, whereas project 2 takes only 1 K dollars, then the less expensive project 2 is more attractive. However, we should like to argue as follows. If the company can make 10 K dollars available for investments, then project 1 generates a positive NPV, whereas project 2 leaves 9 K dollars without a positive NPV. If we want to incorporate the availability of financial funds explicitly, we can turn to linear programming, or mathematical programming in general. Such an approach may also be called for, if we wish to take into account a variety of investment opportunities over time [25)].

What is the practical use of the above investment analysis techniques? Brigham (1976) discusses the application of these techniques outside the computer area. Dean (1968, p.90) shows how many companies actually formalize the view that computer projects are investments. Hall & Lincoln (1976) applied the rate of return criterion in an extensive DP case study. Discounted cash flows are used by the English government; see Head (1975).

Note that the above techniques also play a role in the purchase versus lease choice and the buy or make option. Once the decision is made to go ahead with a computer project, its scheduling may be done using a PERT network or some other technique to evaluate project progress [26)].

In the formulas for NPV, we need to quantify the predicted, future cash flows. These cash flows comprise DP expenses, savings in operating costs, and revenue increases. The quantification of revenues is a difficult subject, discussed in Kleijnen (1979b). Estimating the decrease in operating costs requires the same kind of approach. Remains the estimation of the future DP expenses incurred by a particular project. Such estimation is greatly facilitated by the recording of past costs and expenses for similar DP projects, i.e., by doing cost accounting as discussed in the preceding section. Regression analysis can then be applied to predict expenses for a future project if that project is "similar" to past projects for which data have been accumulated. For instance, in past projects direct labor (the dependent variable) may be mainly determined by such variables as the number of I/0 devices and the number of jobs (independent, explanatory variables). Case studies using regression analysis for the prediction of programming costs, can be found in the references [27)]. Regression analysis based on past, objective data yields objective probabilities.

If no previous similar projects are available, we may resort to expert opinions which result in subjective or personal probabilities. That is, we ask an "expert" (manager, user, staff member) how likely it is that specific outcomes are realized: For instance, the expert may state that the most likely life time of the project is

5 years, and that the probability of life times greater than 7 years or smaller than 2 years is 10% each. Solliciting such subjective probabilities has become quite common, especially in Bayesian statistics and DELPHI techniques. The quantification of subjective probabilities is discussed in many publications [28).

Since the NPV depends on probabilistic variables we want to estimate the distribution of the resulting NPV. The complete distribution may be characterized by a few measures like the median and the 10% quantile.[29)] This distribution may also be used to estimate the probability of "extremes", for instance, a negative NPV. The distribution of NPV can be obtained through simulation (Monte Carlo sampling) also known as risk analysis. Other (less desirable) techniques have also been proposed, e.g. charging a higher discount rate when the cash flow is more uncertain.[30)]

Risk analysis should be distinguished from sensitivity analysis. In the latter case we may investigate the effects of changes in specific assumptions of our model. For instance, a normal distribution or a growth curve may be replaced by some other specification (qualitative change), or the cost of capital p may be changed from 10% to 15% (quantitative change). Sensitivity analysis is also a first step in optimization and satisficing. The satisficing approach is less ambitious but more practical than optimization, and is associated with the "what if" approach. If we want to optimize or satisfice, we may first determine which decision variables (price, sales promotion, R&D) have important effects on our criterion (NPV). Factors to which the criterion is not very sensitive, can be ignored in the search for an optimal or satisficing solution. Note that in sensitivity analysis we change the input variables and model assumptions systematically (not randomly as in risk analysis) and have the values of variables and parameters vary over the whole range they can assume. Fisher

(1971) gives several approaches and examples of sensitivity analysis. His examples demonstrate that if many "factors" (variables, parameters, assumptions) are studied, it becomes difficult to determine which factor combinations to investigate and how to interpret and generalize the great mass (or mess?) of output data. Elsewhere we discussed the use of a "metamodel" or auxiliary model.[31] Such a metamodel formalizes and extends the following common sense procedure: A practioner might change one variable x, observe the resulting output y, repeat this procedure , plot the (x, y) combinations, fit a curve by hand, and decide whether x affects y. We formalized this hand fitting by the use of the least squares algorithm, extended the procedure to multiple inputs, and systematized the steps. We further emphasized the role of interactions among input factors.[32] Note that the selection of factor combinations to be investigated, is part of traditional statistical theory, and is known as experimental design[33].

6. Conclusions.

We surveyed a number of topics mainly taken from microeconomic theory. We explained and criticized the market mechanism. We further indicated how the general economic theory applies to the products "information" and "computers". Special attention was paid to the inadequacy of the market mechanism for solving the benefit evaluation problem for information products within a company. This lead us to the charging and pricing of computer jobs. Such a practice is useful for efficiency control and resource allocation. Next we discussed the investment character of data processing projects, using Net Present Value, risk analysis (Monte Carlo sampling), and sensitivity studies (using a metamodel).

NOTES

1. $C=K\sqrt{E}$ with costs C, effectiveness E, and constant K.
2. Cotton (1975), Sharpe (1969), Selwyn (1971), Phister (1976).
3. Hoyt (1975).
4. Couger & Knapp (1974).
5. Kleijnen (1975 b).
6. Emery (1971).
7. Cotton (1975).
8. Lin (1976), Mishan (1971).
9. Cooper (1973), Keeney & Raiffa (1976).
10. See also Flowerdew & Whitehead (1975).
11. Brock (1975), Cotton (1975), Sharpe (1969), Phister (1976).
12. Cunninghame-Green(1973), Willoughby (1975).
13. Brock (1975).
14. Sharpe (1969).
15. Bernard et al.(1977).
16. See also Welke (1977).
17. Bernard et al. (1977), Itami (1973).
18. Fisher (1971), Cotton (1975), Emery (1971), Sharpe (1969).
19. Bernard et al. (1977), Smidt (1968).
20. Bernard et al. (1977), Kleijnen(1979 b).
21. Bernard et al. (1977).
22. Additional references: GAO (1976), Hamilton (1977), Hootman (1977), Palmer (1975).
23. Fisher (1971), Sharpe (1969).
24. Menkhaus (1969), Schwartz (1969); also Fisher (1971).
25. Bussey (1978), Levy & Sarnat (1978).
26. Grindley & Humble (1973), Brooks (1974), GAO (1976).
27. Chrysler (1978), GAO (1967), see also Fisher (1971) for a non-computer oriented exposé.
28. Huber (1974), Spetzler & Holstein (1975).
29. The 10% quantile, say q_{10}, is defined by $P(x \leq q_{10})=0.10$.
30. Fisher (1971), Gitman & Forrester (1977), Sharpe (1969).
31. Kleijnen(1979 a).
32. For interactions see also Ein-Dor & Seger (1978).
33. Kleijnen(1975 a).

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