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FOR ENGINEERING AND SCIENCE

A Plow For Mexican Peasant Farmers

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Description

A hypothetical case study and design project that asks engineers to consider the values at issue their work and the social ramifications of technology.

Abstract

There is a pressing need for a device to assist third-world peasant farmers in cultivating their small plots of land. None of the plows currently available adequately fill this need. This case involves the design of a plow that fits these specifications.

Most of the other cases in this series are actual cases in which issues of engineering professionalism and ethics have arisen. By contrast, this is a design project. The focus here is not on a moral evaluation of the actions of particular engineers, but rather on identifying and intelligently addressing the value issues that arise in an engineering design project. The case helps students to see that the introduction of new technology can have profound implications for a community. Therefore, it raises question of engineer's responsibility for the social consequences of their work.

Body

Instructor's Guide

A Challenge for Designers

There is a pressing need for a device to assist third-world peasant farmers in cultivating their small plots of land. This need has never been satisfactorily met by any of the plows currently available. This case involves the design of a plow which can fulfill this need.

The plow should be assisted in some way by a gasoline engine, but the precise nature of the assistance the engine will provide is a matter for the designer to determine. For example, the engine might be used to pull the plow, but it might also be used to vibrate the plow, making it less difficult for animals to pull the plow. Other ways of using the power from the gasoline engine may be possible. Although the plow would probably be appropriate for use in any third-world country, we have specified that it will be used in Mexico. This gives the design project an additional note of realism and direction.

There are a number of other important design considerations. (1) Most peasant farmers in Mexico and Central America have hillside plots, the more desirable land being in the hands of large landowners. So a plow with a high center of gravity which would be easily overturned would not be appropriate. (2) The plow should probably be designed to be operated by one or at the most two people; but farming is usually labor-intensive in third world countries, and the need for additional people to operate the plow would probably not be an obstacle. (3) The plow should be relatively simple to operate and maintain; replacement parts must be easily available. (4) Finally, the cost should be under \$1000.00.

Uniqueness Of This Case

This case differs in important ways from most of the other cases in this series. Most of the other cases are real world cases in which issues of engineering professionalism and ethics have arisen. By contrast, this case involves a design project, although the design is intended to meet a real-world problem. The focus here is not on a moral evaluation of the actions of particular engineers, but rather on identifying and intelligently addressing the value issues that arise in an engineering design project. The case helps students to see that the introduction of new

technology can have profound implications for a community. It is thus an effective means of impressing on young engineers their responsibilities for the consequences of their professional work.

This particular problem is specifically oriented toward a senior design course in mechanical engineering, and it is not appropriate for chemical, electrical, or civil engineering. However, instructors who do not find this particular case appropriate for their own classes may still find that it is a useful model for something they might do in their professional area. The instructor who developed this case chose it in part because of the obvious value dimensions inherent in it. But there are cases in every area of engineering that can illustrate the value aspects of design.

The Hidden Dimension

There is a tendency on the part of professionals to overlook value issues in their work. Consider the following simple illustration from medicine. Suppose a physician must decide whether to administer a more powerful analgesic to her dying patient who is suffering from increasingly high levels of pain. On the one hand, if she does not prescribe the more powerful analgesic, the patient will be in considerable pain that could be eliminated. On the other hand, if she prescribes a more powerful analgesic, the patient will not suffer pain, but he will not be able to think as clearly and to relate to his family as effectively during the last days of his life. Should the physician administer the more powerful analgesic?

A decade or more ago, most physicians might have said that this question involves a "medical" decision and that the physician should make the decision. Today, many physicians are willing to concede that questions such as this are not primarily medical decisions, but rather value decisions that, under normal circumstances, are better left to the patient.

This is of course a very simple example, but it illustrates the way value decisions are often unrecognized by professionals. Professionals are predisposed to appraise issues from the standpoint of their own fund of technical knowledge. This is for the most part entirely proper, and it is what they have been trained to do. There is a weakness in this approach, however, namely that it tends to obscure the fact that some issues are not most appropriately dealt with from the perspective of their professional knowledge. As the above example illustrates, some decisions are primarily matters of values. This affects not only the criteria appropriate for a

decision, but also the decision as to who should make it.

The engineer's work contains many such buried value decisions. Training in the ability to distinguish genuinely technical issues from value issues--or the ability to distinguish the value aspect of a technical decision from the more purely technical aspects--is an important aspect of the professional training of engineers. Just as the physician who did not recognize the value dimension of the decision whether to prescribe an analgesic to her dying patient should be considered in some way professionally deficient, so engineers who do not recognize the value dimension of their professional work should be considered professionally deficient.

Questions For Discussion

The following series of questions may serve to increase the students' awareness of the ethical dimension of this design project.

Will the Plow Be Perceived As Foreign Or Alien?

Anthropologists who have studied peasant cultures in Mexico and Central America emphasize that anything brought into such cultures from the outside and perceived as foreign or alien can be very destructive to the culture. It can also be detrimental to the self-esteem of the people who use it.

The peasant farmers in Mexico, many of whom are Indian, are very sensitive to the differences between their way of life and the way of life of the "white man." The "white man" includes not only Anglo Saxons from the United States, but also Mexican descendants of the Spanish invaders. The Indians often view anything brought in from the outside as an indication of their own inferiority. The acceptance of such imports implies, they believe, that the white man knows how to do things better than they do. Sometimes they will reject the imported item and not use it. Sometimes they will use it, but the result will be culturally or psychologically destructive. At other times they can incorporate the item into their culture in a more positive way.

Thus a very serious question arises as to whether a mechanically-powered plow would have a beneficent impact on the indigenous cultures into which it is introduced by making their method of farming more efficient and their way of life more sustainable, or whether it would tend to disrupt their culture and contribute to

its destruction.

Here is a case where there is an ethical issue demanding choice, whereas one might not have seen an ethical issue at all. It is an example of the way ethical issues lie hidden under the surface of considerations which appear purely technical.

There are, however, several ways in which an engineer might attempt to evade any responsibility regarding the ethical questions that this issue raises. For example, she might argue that this kind of consideration is not her concern as an engineer. But this relies on a narrow conception of responsibility. If a person's being a causal agent with respect to an event gives one a share in the responsibility for it, then a designer has a share in the responsibility for the effects of the plow.

A second argument might be that the degree to which peasants can incorporate a plow into their culture is determined more by the way the plow is marketed to the peasants, and this is an issue over which engineers have no control. There is a considerable degree of truth in this response, but it still seems inadequate. As we shall see in the next section, some of the factors that determine the ability of the culture to assimilate the plow are directly affected by the design, and these are factors over which the engineer does have a say. So engineers do share in the responsibility for whether or not the plow can be assimilated.

Finally, an engineer might say that primitive peasant cultures should be assimilated into the dominant, more western-oriented culture of Mexico. If the plow he designs contributes to that end, this is one of the fortunate consequences of the creation of the plow. Whether or not this view is correct, it is clearly not a value-neutral position. It shows even more clearly that the engineer cannot wholly escape responsibility for the value dimensions of her work.

A number of factors might determine whether the plow will be perceived as an unwelcome import from a foreign and hostile culture, including such simple things as what color the plow is painted. Some colors may have special meanings for the culture, and they may be important determinants of who uses the plow and what significance it has in the culture. For example, some colors may be more associated with one gender than the other, or one social stratum rather than another.

Here are some other questions that are also important for the significance of the plow.

For Whom Should The Plow Be Designed?

If the plow is used by the wealthier and more competent and enterprising members of the peasant community, it may be used most effectively. This may have the result, however, of putting these members of the community even further ahead of their neighbors. If the plow is used by the less talented members of the community, it may not be used effectively, and the community may not make as much economic progress.

Which value is more important, community solidarity or economic progress? Is there any way to achieve both ends? Could this be incorporated into the design of the plow? For example, the cost of the plow is an important determinant of who will use it.

Several other factors might be important in deciding which group would be more likely to use the plow. The simpler the construction and the more easily repairable the plow is, the more likely it would be that the less advantaged peasants would use it. The important thing for the student to see is that these kinds of ethical issues are raised by the question about the group for which the plow is designed.

Will Humans Or Animals Be Used To Pull The Plow?

Animals are an important part of many traditional cultures. Mechanical devices that make animals useless, or even less useful, can be important determinants of social change. We have already pointed out that it is possible to design a plow that is pulled by an animal, but has a motor to vibrate it or in some other way move the blades so the plowing can be done more easily. Human power is even an option in some cultures. Would this be desirable?

The care and association with livestock is important to peasants' sense of self and social place. Animals are also a kind of insurance for peasants. If times get too hard, the animals can be sold to help sustain the family. If animals are not used for draft purposes, they would be idle much of the time. On the other hand, animals may be a significant drain on the limited food resources of some groups. Perhaps the reduction in the number of animals the peasant would have to support would be a benefit to him.

Is The Design Of The Plow Sensitive To The Gender Of The Operator?

In some traditional societies, women do most of the farming. If the plow is not suitable for women, the introduction of the plow into the community would be disruptive of traditional ways. What design considerations are relevant here? For example, some plows might be too heavy for women to use. A heavy plow might be too difficult for women to turn at the end of the row. If a heavy plow overturned, some women might not be able to set it up again.

If, in a given culture, women do not do farming and their exclusion from agricultural work is one of the reasons for their subservient status in the culture, a plow suitable only for men would perpetuate these conditions. A plow suitable for women would be a vehicle for raising their status in the society. But then this augmented status might be highly disruptive to the society, and the need to be "liberated" might be something that the women of the culture do not recognize. Is it morally permissible for outsiders to, in effect, mandate change by introducing revolutionary technology? Perhaps the engineer should strive to make the plow "gender neutral." If so, she must know how to do this.

Will The Operator Of The Plow Walk Or Ride?

The change from walking to riding or riding to walking is a significant one. In general, walking behind a plow is probably better for the operator's health, but it might not be desirable from a social standpoint. For example, riding might have more social status than walking. Whether one walks or rides might also be related to the perception of whether the work of plowing is appropriate for men or women. Finally, safety issues might be important considerations in whether the operator of the plow walks or rides.

Should The Plow Be Designed At All?

Technology makes such a profound impact on a culture that there is always a question whether a particular technological artifact should be created at all. Some technological innovations have clearly been more destructive than constructive. It is possible that the Lorian stove discussed in the student handout should never have been produced. The question about the ultimate value of a technological innovation is often difficult to answer, but it is one which an ethically sophisticated designer

should consider.

Three final observations should be made. First, a designer cannot answer all of the questions we have posed here. In order to do so, she would not only have to do an enormous amount of research, but she would have to know the particular social group for which the plow is being designed. Many of these questions would be answered in different ways for different social groups. Since the plow is presumably being designed for a large number of cultural groups, the designer cannot design the plow so as to accommodate only one such group. Perhaps, though, the engineer could design the plow so that it would be as adaptable as possible to the demands of different groups.

Second, the purpose of this discussion has not been to cause an engineer to be so obsessed with the cultural and ethical aspects of her work that she loses sight of more narrowly engineering considerations. Rather, the purpose has been to broaden the horizons of students, so that they will be more aware of the fact that design work does have social consequences. Engineers, like most of the rest of us, tend to forget the wider implications of what they do.

Third, this discussion also serves to raise the issue of "problems of conscience" as they arise in engineering work. Engineers sometimes object to working on a project for moral reasons. Some engineers do not want to be associated with military projects. Others object to working on projects (such as dams or projects that involve draining wetlands) that they believe are destructive to the environment. Similarly, an engineer might believe that this plow should not be produced because it would have a negative impact on the culture of those who would use it. Should he or she be given the option of working on another project?

The ability of a firm to assign other work to an engineer depends in part on the size of the firm, but the larger issue is whether engineering societies should be more active in promoting the rights of engineers to object to work on the basis of a problem of conscience. Should engineering codes have a statement that at least encourages firms to provide alternative forms of work for an engineer who has a problem of conscience in working on a particular project? This is an interesting question to raise with your students.

Instructors preparing to lead classroom discussion on this case will find particularly relevant essay #4, "Engineering Design: Literature on Social Responsibility Versus

Legal Liability," appended at the end of the case listings in this report. In addition, essays #1 through #3 appended at the end of the case listings in this report will have relevant background information for the instructor preparing to lead classroom discussion. Their titles are, respectively: "Ethics and Professionalism in Engineering: Why the Interest in Engineering Ethics;" "Basic Concepts and Methods in Ethics;" and "Moral Concepts and Theories."

Recommended Overheads

The overhead can assist the students in gaining a better understanding of some of the issues involved in this case. Here is a short explanation of the overhead:

1. Two tables which give the student a sense of various costs per hectare for the small farmer, and the distribution of mechanization between the developed and underdeveloped countries.

A Plow For Mexican Peasant Farmers

Overhead

1) Relevant Tractor Farming Data

Size and Costs of Tractor-Powered Operations

Concept Farm Size (ha)

	1	2	4	8	16	32	64
Optimum tractor size (hp)	1.5	2.3	3.9	7.0	12.9	24.8	48.5
Annual fixed cost (kg/ha)	375	287	244	219	202	194	189
Annual labor costs (kg/ha)	279	176	105	59	32	17	9
Annual cash capital costs (kg/ha)	745	565	446	373	330	307	294
Annual timeliness losses(kg/hg)	93	118	140	158	171	178	182
Total Annual Cost (kg/ha)	838	683	586	531	501	485	476

Annual hours of operation	186	235	280	316	341	363	367
Cash and capital costs per unit work (kg/hp-hr)	2.71	2.05	1.62	1.36	1.20	1.12	1.07

Distribution of the Cultivated Area According to Stages of Mechanization in 1975

Concept Stage of Mechanization

	Manual Work	Draught Animals	Tractors	Total
Developing Countries				
Cultivated area 106 ha	125	250	104	479
Relative percentage %	26	52	22	100
Developed Countries				
Cultivated area 106 ha	44	63	537	644
Relative percentage %	7	11	82	100
World				
Cultivated area 106 ha	169	313	641	1123
Relative percentage %	15	28	57	100

NOTE: Both tables were obtained from: FAO, The State of Food and Agriculture, 1988.

A Plow For Mexican Peasant Workers - Student Handout

Synopsis

In Mexico, as in many third-world countries, those who are engaged in agriculture can be roughly divided into two groups: large landowners and small subsistence farmers. For the most part, the large landowners have done a good job of keeping

up with technological changes, and they have had the financial ability to utilize those changes. For the poor farmers, the situation has been very different. While the Mexican government has taken some steps towards land redistribution, 65% of the farmers hold less than 5 hectares of land. This diminishes the advantage of technology, which usually depends upon scale. Further, the land owned by these farmers is in the hills and mountainous terrain. It's difficult to transport and manipulate large machinery in these areas. Finally, water projects for increasing irrigation have generally not benefited the rural population, which remains dependent on the rains.

If large farms can achieve efficiencies of scale, small farms will be unable to compete and may eventually be driven out of business. One might argue that it is better to let these small farmers get out of the agricultural business altogether. By allowing large farms to produce the agricultural needs for Mexico, the peasants can be moved to populated areas to work in industry.

Yet this solution seems patently wrong for three reasons. First, agrarianism is an important part of the Mexican cultural heritage. Many peasants want to remain close to the land and to continue to be a part of rural life. Second, the agrarian economy can support many more individuals than the industrial sector of Mexico. Prior to the 1970's, Mexico's economy was expanding due to the influx of petro-dollars, and advances were being made in reorienting Mexico's population towards a Western model. However, with the rise of inflation in the seventies, and a crushing foreign debt load, those advances stopped.¹ Thus, if a way could be found to increase agricultural yields without forcing rural flight, the economy as a whole would benefit. Finally, the agricultural sector has had difficulty in recent years meeting goals of self-sufficiency for production of staple crops, such as maize and beans. It would be highly desirable, then, to increase yields on all available farmland.

Since supporting small farms is important to Mexico's immediate future, making small farming more efficient is an immediate need. One way of doing this is by producing a small plow that is appropriate for subsistence farming. Such a plow might increase crop yields and also lessen the backbreaking work of hand farming.

The development of a small plow might not be an unmixed blessing, however. Your instructor will present some reasons for thinking such a development might have negative effects. The following discussion presents some of the relevant considerations.

A first consideration for anyone interested in mechanizing small farming is that the rural economy places considerable value on animal ownership. Draft animals can be used for plowing and transport, and the calves can be sold for meat. In fact, a draft animal is an important asset for the farmer, because it can be sold if he is in financial distress. How a mechanization project affects animal ownership is thus an important consideration.

A second consideration is that the small farmer is very risk averse. More technologically advanced farming might provide 120 bushels one year and 25 bushels the next, whereas less advanced farming might produce 60 bushels of maize in a good year and 50 in a bad year. Given the choice between these two options, the small farmer would probably choose the second. This is because the small farmer is interested first in providing for his family, and only then selling for profit. Thus, if the costs of operation of a plow are too high, or detrimental to the soil or has other features tending to increase risk, farmers may not adopt it. Even if the plow is provided to them without charge, they may not accept it if it is perceived as substantially increasing risk.

Another consideration is that care should be taken lest technology is seen as foreign, or as an affront to the culture of the farmers. Artifacts seen as foreign sometimes convey the wrong cultural message: "their way is good and ours is bad." This tends to undermine cultural identity and social solidarity. Technological artifacts with which people can identify, and which can be seen as supportive rather than destructive of their culture, will be more likely to be accepted.

The history of the Lorian stove is often used by anthropologists as an example of the problems of introducing Western technology into non-Western societies. The stove is twice as efficient in its use of wood fuel as the indigenous Guatemalan peasant stove. But the Mayan Indians think of it as something non-Indian. The use of the stove is interpreted as an admission that the technology of others -- i.e. of the Spanish and North Americans -- is superior to Indian ways. There is another problem with the Lorian stove that emphasizes the importance of knowing the audience for whom one is designing. The stove gives off less heat than the traditional Indian method of cooking. Even though this is connected with its greater efficiency, it has a disadvantage. The main heating source of Indian housing is the stove. Use of the Lorian stove by Indians in the mountain regions of Guatemala means their homes are cold. If the designers had known this, they might have decided that making a more efficient stove should not be one of the design goals. They might have even

decided that the Indians did not need a new stove.

Here is a final consideration. One means used to assist in making decisions about technology is cost/benefit analysis or highest utility analysis. This method requires the engineer to select the design option which will produce the greatest benefits relative to cost. This method has come under considerable criticism, however. One criticism is that the benefits could be maximized without being equitably distributed. The best way to maximize the total benefit from the plow might be to provide plows to the most ambitious and capable of the small farmers. They would probably use the plow most efficiently. The plow might also enable the more capable farmers to become even wealthier, relative to their less capable and ambitious neighbors. The overall utility might be highest, yet the distribution of wealth resulting from this approach could be even more uneven. One might argue that rewarding efficiency is a good thing for the society, but this is a value judgment. The important thing to keep in mind is that introducing Western technology can initiate important social changes.

We tend to assume that technological improvement is always a good thing. Unfortunately, introducing new technology may destroy or seriously modify a culture, and this may or may not be desirable.²

Cost/benefit analysis is only useful if it can specify and quantify all relevant factors in a decision. Obviously we do not have perfect information for any case, but if cost/benefit analysis systematically undervalues certain aspects, such as cultural or moral factors (as Thompson argues), then the decision made on the basis of cost/benefit analysis will be flawed.

In the end, the choices made in designing the plow are going to have many ramifications. One writer has pointed out that:

the telling fact is that agricultural science and technology, like all technologies, have no inherent value; their human value is manifested only by the results achieved when they are properly applied to serve the need for which they were created.³

Design Considerations

Here is a list of considerations that you should keep in mind when designing the plow:

1. The plow could be designed to require two or more operators. Generally there is an abundance of human labor in subsistence farming.
2. The plow should not cost more than \$1000.
3. The plow should be easily maintained. The tools available for repair will probably be minimal, and the level of mechanical expertise will probably be low. Also, the parts should be easily available.
4. The plow should be easily operable. The operators will have minimal skills with machinery, and extensive training would be impossible.
5. The plow should use fossil fuels that are readily available.
6. The plow could either move under its own power or be pulled by a human being or a draft animal.
7. If possible, the plow should be safely operable on slopes of up to 30 degrees.
8. The plow should be able to cultivate to a depth of 2-12 inches. The adjustments that vary the depth of plowing should be easy to make.
9. The plow should be able to cultivate more than .2 hectare/day; which is the amount of cultivation that could be expected if draft animals were used. Since the operating costs of a plow are greater than the maintaining costs of an animal, the greater efficiency of the plow should offset this cost.
10. Preventive maintenance should be easy. Parts will be difficult to come by, and factory service technicians may be nonexistent. Any maintenance which can prevent problems before they occur will add significantly to machinery life.
11. Since the storage and transport of fuel is an expense, a plow having a large gas tank is desirable.
12. Mexican gasoline's octane rating is quite low. The compression ratio of the engine will have to be low, with a lower specific horsepower rating than would be normal with higher octane fuel.

Problems With Small Plows

Obviously, given the price constraint, the engine is going to be small. Unfortunately, the small engine plows in use have numerous problems. These are enumerated in a very useful text entitled, *Agricultural Mechanization in Development*, by R.C. Gifford.⁴ Here are some of the difficulties of small plows (518 hp) according to Gifford:

1. **High operation cost.** Small engines must operate at higher r.p.m. to gain the torque necessary to pull a heavy implement. Because of this, maintenance and repair costs will be higher than with larger engines that can operate at lower speeds.

2. **Low traction.** The average tractive efficiency of regular tractors (say, 50 hp) is about 46%; for small tractors, the efficiency is 1734% less. Traction is a function of the weight of the tractor and its ability to turn that weight into traction for the tires. Obviously the smaller the tractor the less weight available. A second problem with traction in smaller tractors is the limitations in the size and width of tires they can use; this also leads to low traction. Low traction will lead to difficulty in cultivation in heavy or dry soil conditions.

3. **Low stability.** A single-axle plow's stability is limited by the ability of the operator to prevent the machine from tipping. If the slope of the land where the tractor is used is steep and the ground rocky and hard, the plow can skip and twist over the earth. Small two-axle tractors are limited in the width and length of their wheel base. This leads to the same problem Jeeps have, namely the tendency to tip over easily in sharp turns or on slopes. Yet a short wheel base and high ground clearance are necessary for a plow which can operate in difficult areas such as small, irregularly-shaped plots. Thus a trade-off between stability and mobility is often made in the design of the machine.

4. **Low operator comfort.** Operator comfort is often slighted in favor of power and design constraints. Yet being able to operate a machine comfortably for long time periods increases both productivity and safety. Unfortunately, price constraints limit the designer's ability to make both economical and well-designed tractors.

5. **Safety problems.** Safety of operation can be improved by considering ergonomic factors, as well as the lay-out of proper drive shafts and moving parts. It can also be improved with features which protect the operator from the machine. In designing small tractors, however, ergonomic factors are often given scant attention. As for safety features, these may work well when the plow is new, but a scarcity of parts

and proper servicing may result in their degradation with time. Usually, there is little in the way of operator training. This tends to increase safety problems. Finally, small tractors have fewer safety features to begin with than larger ones.

6. Referring to the small tractor, Gifford concludes that "in spite of the seemingly attractive low cost it is more costly per horsepower to manufacture, and more costly per hectare of output to operate, than conventional tractors."

Engineering Data and Questions

Here is some additional data for your calculations:

1. $Hp \text{ (metric)} = \text{Draft} \times \text{Plow speed} - 375$
2. Width of Implement usable with = Max draft - a given tractor Draft/meter
3. Values for Draft/meter
 - a. Mould board plow 224.7 Newtons
 - b. Chisel plow 179.7 Newtons
 - c. Disk (medium draft) 67.4 Newtons
4. Plow Speed = 1 meter/second
5. Usable Drawbar horsepower (power to pull the implement) is 67% of max or stated horsepower.
6. Plow field capacity is a measure of the distance covered in a given time.

Annotated Bibliography

This bibliography is divided into two groups. First there is a set of references relating to the value issues involved. Then there are references relating to the engineering issues.

Value Issues

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Notes

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