

Feasibility Study for Local Production of Microfilm in Mali

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ABSTRACT and RECOMMENDATION

Microfilm content tailored for local learning is an integral component of the Kinkajou project currently underway in Mali. Here we review the current method of obtaining microfilm and present different scenarios for producing microfilm in-country. Special attention is paid to pricing and shipping, and a short background of the filming, developing, and duplicating processes is given. This analysis assumes that films will be bitonal, though there is a short discussion of color microfilming. While not impossible, it would be difficult to set up a micrographics laboratory to service the Kinkajou in Mali at this time. Previous efforts in the area have struggled with high capital costs, lack of trained technicians, and environmental difficulties (e.g. dust, high temperatures). According to price models, for every scenario, contracting microfilming services to firms in the US will be cheaper than local production. This price difference is most marked when the capital costs are high and assumed volume is low, such as for the filming and developing segments of the process. However, when considering just the duplication segment of the process when volumes are high, the price difference per reel between US and in-country production falls dramatically.

- **Recommendation 1-** If the Kinkajou remains in relatively low numbers in Mali ($n < 2000$), microfilm production should be contracted outside the country. The case for this is particularly strong if the number of Kinkajou clients is low and curricula are updated infrequently.
- **Recommendation 2-** If World Education or another client significantly increases the number of Kinkajous in Mali ($n > 5000$) and has the need for high volumes of duplicate films for multiple curricula, it may be beneficial in terms of flexibility and turnover time to locate a duplication-only micrographics laboratory in Mali.

Figures of Merit-

Cost of US master production:	5 cents/page
Cost of US color production:	\$150 + \$1/page (average)
Cost of US diazo duplicate:	\$5- (including cost of blank film)
Cost of US shipping to Mali:	\$90 (for single master copies) \$2.30/reel (for shipments of $n > 300$)
Cost of blank film from US	\$8.30/reel
Cost of Mali master production:	\$634- (after 50 runs on the equipment, ~780 pages)
Cost of diazo duplicate:	\$12.80 (for orders of $n \sim 1,000$) \$9.20 (for orders of $n \sim 10,000$)
Price difference for volume duplicates:	\$1.90/reel

A. Review of Microfilm Contracting by World Education

The finished curriculum was sent electronically to Virtual Image Technologies (VIT) in Fort Mill, SC. This was then printed onto both “positive” (clear background, black lettering) and a “negative” (black background, clear lettering) master copies. These were forwarded to Design that Matters in Cambridge, MA for evaluation. The masters were found to be satisfactory and were sent back to VIT, who then produced duplicate copies and forwarded the order to World Education. The entire process took about 3 weeks. Invoicing was done by World Education, but the price quote from VIT was approximately US\$100 for the masters and \$10 for each duplicate, inclusive of the price of the films.

B.1 Producing content in Mali

One of the major potential obstacles to the Kinkajou being adopted on a large scale is the problem of local content manufacture. In this section we will explore in detail the different scenarios for this. In the case of our existing client, World Education in Mali has expressed an interest in producing the films in a central location for distribution to its satellite schools. Since Bambara is not spoken widely (if at all) outside of Mali, it makes sense for the cohesion of the project to locate the development, production, and usage of the films all in-country. It may help the educators, students, and other persons involved to feel certain ownership of the project, as well as pride in something locally made. Also, a local laboratory has the potential to create employment and training opportunities for its technicians. We will also examine the plausibility and cost/benefit of individual teachers ordering custom microfilms for their classrooms. This decentralized approach would allow for huge flexibility in the usage of the Kinkajou and is in many ways a best-case scenario. Teachers would be able to develop their own lesson plans, exams, diagrams, and other materials onto film, enabling them to become local educational innovators.

West Africa in general, and Mali in particular, presents a difficult environment for microfilm production given the climate, scarcity of the required processing chemistry, and lack of distribution channels. Microfilm was chosen as the film medium because of its durability and low cost relative to digital displays, as well as its small size and high compression relative to other film media. Results from the field testing will shed some light on this assumption of durability.

B.2 Local usage of microfilm (in archives, libraries, schools)

It appears that there are no facilities for the production of microfilm in Mali currently. Also, from a brief survey of the major universities, the National Library, the National Archives, and the National Museum, we found that only the Museum had any microfilm in stock for viewing. This had been made in the US and supplied from Toumbouctou. Therefore, any effort to establish microfilming capacity in Mali will require a building a laboratory from the ground up and the necessary training of technicians.

B.3 Scenarios

We will consider four scenarios for microfilm production for users in Mali. The current model is to contract all work to micrographics firms outside of Mali (specifically, to a firm in the US). The most radical choice would be to set up an entire laboratory facility in Mali, complete with filming, developing, and duplication of the films. This is by far the most complex choice, logistically speaking. The two remaining scenarios are in the middle ground, contracting out certain steps of the process and performing the rest on-site in Mali. We will examine each in turn, with a particular eye on cost and on factors (such as scale) that would affect our recommendation.

Scenario 1 – Contract everything outside

This is the current practice for getting microfilms made for use with the Kinkajou, as explained in Section A. Here we present a more complete picture of the process, optimized for cost. Because of the capital expense required to set up a micrographics facility and train technicians, particularly in an area without any existing industry infrastructure, this option is the simplest. For low-volume filming and duplication, it also turns out to be the cheapest.

- **Ship paper/email (bandwidth issues)**

Most of the micrographics services companies do not require paper copies of the material to be filmed, so the only factor in getting material to these companies is the internet bandwidth available to Kinkajou users in Mali. If scanning from handwritten paper, the required resolution is 200dpi for text and 400dpi for grayscale or pictures, both of which are well within the range of standard low-end scanners.

- **Comparison Shopping**

There are micrographics companies all over the world that provide document services in the form of microfilming. The greatest concentrations of these are in the UK, the US, and Germany. Micrographics labs in Africa include those in Egypt, Morocco, Nigeria, Kenya, Ghana, and South Africa. Due in part to the weak dollar, firms in the US currently offer the most competitive rates for filming, at around 5 cents per page (inclusive of the films). Since there are no capital costs under this scenario, the cost of producing masters and duplicates per roll does not increase or decrease with scale. However, the price of shipping does decrease slightly. For large orders of duplicates, the price per roll (incorporating the price of the master) is approximately \$7.30.

- **Shipping costs/times**

For large projects such as the pilot with World Education, shipping times are not a major concern. However, in thinking about how educators might use the Kinkajou, it is very possible that someone might want a quick turnaround for film production. In general, the fastest shipping routes to Mali are from the UK and France, and the most cost-effective is from the US. It is clear that, due to the high price of shipping, individual teachers will be unable to transfer local content onto microfilm under this scenario. Shipping time is also a factor, as many local educators do not write up lesson plans for their classes very far in advance.

- **Import/Export restrictions**

When shipping overseas, it is necessary to declare items for customs. Microfilm commonly has its own shipping code and is permitted in most countries. Interestingly, in Morocco and Egypt, countries which have microfilming capabilities, microfilm is not a permitted material for import or export. Presumably, the microfilm produced in these countries is used domestically in libraries and government institutions. These countries, then, are not viable options for contracting micrographics work outside of Mali.

Scenario 2 - Full lab in Mali

This option presents the most difficulties logistically speaking, but also provides the most flexibility in content production. Educators and other Kinkajou users would be able to obtain custom microfilms easily and quickly. A dedicated micrographics lab would provide employment and technical experience for technicians. Also, local manufacture of microfilms may inspire pride in the project and enhance educators' sense of ownership. This can only increase the quality of education supported by the Kinkajou.

Since there is no microfilm infrastructure currently in Mali, setting up a lab will require the following:

- Finding dedicated space, with plumbing hookup and room for chemical storage
- Purchasing and calibration of equipment
- Training of technicians
- Building of relationships with chemical and film vendors

Cost is a major factor here. Due to the high capital costs of the necessary equipment and relative scarcity of the needed chemistry, it is only realistic to consider a central facility in Bamako.

▪ **Equipment**

The process of producing microfilm can be broken down into three separate steps:

1. Prepping and Filming, which requires a camera, a filming table, and blank films;
2. Developing, which requires a processor, attendant chemistry, and a densitometer for quality control; *and*
3. Duplication, which requires a duplicator, attendant chemistry, and blank films.

What follows is a brief description of the specifications, functions, and requirements of each piece of equipment¹:

Cameras – There are two types of microfilming cameras, planetary and rotary.

‘Planetary, or flat-bed cameras are used for applications where the highest possible quality is required. Because both the document and the film are stationary during exposure it is possible to achieve maximum image resolution on the film. Other advantages include the provision of infinitely variable reduction ratios by altering the distance between the camera and the document. The main disadvantage is that the process tends to be slower than rotary filming. Automatic document feeders are available for a few planetary cameras, but documents are normally positioned, filmed, and then removed by hand. Resolution is not usually constant throughout the full range of reductions, but most planetary cameras can record at a minimum of 125 lines per mm. Some cameras feature automatic control of image density so that varied input produces identical images. This greatly simplifies subsequent operations such as duplication and printout.

‘Rotary filming is considerably faster than planetary filming because it is performed as a continuous operation and most rotary cameras have an automatic document feeder. Pages are filmed as they pass through the camera and the relative speeds of the film and documents are carefully synchronized to maintain good image resolution. The reduction ratio is usually determined by the camera unit. Widely available options include the ability to film both the front and back of each document, presenting the images side by side across the width of the film in duplex format. Alternatively, documents can be filmed along one half of the film width and then back along the other half in duo format.’

- **Recommendation**- Given that the project makes use of microfilm as a medium for information dissemination, duplication of master films is the most important step. We

¹ Excerpted from www.green-sheet.net.

would expect filming and processing for the master copy to be low-volume relative to duplication, so the speed of filming is of little importance. Given the purpose of the films, high image quality is not required. The remaining parameters are cost, size, maintenance, and flexibility. The two camera types do not differ significantly in cost; rotary cameras are generally smaller, less fragile, and require less maintenance; planetary cameras are more flexible regarding image reduction and could therefore service many more types of orders. Considering all of this and the harsh environment in Mali, we would recommend a rotary camera such as the Kodak MiniMicrofilmer.

Processors

‘Most silver halide cameras only expose film. Before it can be read or duplicated it must be processed, fixed, washed and dried. Film processing using wet chemicals is the activity which causes most concern for those planning the use of microfilm, but modern processors for office use are simple to operate. Alternatively, films exposed on an in-house camera can be sent to a local microfilm bureau for processing and producing as many duplicates as may be required. Conventional film processing transports the exposed film through liquid developer to convert silver halide grains, which have been exposed to light, to metallic silver. This conversion is sensitive to time and temperature. Strict control of both the heat of the chemicals and the speed of the passage of the film through them is necessary for consistent results. A rinse may follow to remove any surplus developer and it may contain an acid stopping agent to arrest any further growth of the grain size of the silver particles. A stop-bath also helps to avoid staining and streaking of the film and prolongs the working life of the fixing solution. The next stage is fixing in a solution usually composed of sodium or ammonium thiosulphate which dissolves all undeveloped silver salt. The film is then thoroughly washed to remove residual developer and dried before being wound on to reels, delivered as cut fiche or in aperture cards. Conventional processing produces a negative image with clear print on a black background because the parts of the film emulsion that have been sensitized by light turn to black silver and the parts which did not receive light (the print on a page for example) are washed away leaving virtually clear film.

‘The camera employed to expose the film, the number of films being produced per week and the purpose for which they will be used will determine the choice of an in-house processor. Many cameras hold films in light-tight magazines to allow daylight handling and when these are used it is important to ensure that a suitable attachment is available for the processor. Simple processors may only control the temperature of the developing and fixing solutions. For critical applications it is undesirable for too great a difference to exist between the temperature of the developing, rinsing, fixing and washing stages, and control of the temperature of all tanks can be an advantage. Water consumption and the disposal of waste water and chemicals are points to consider when contemplating in-house processing.’

- **Recommendation-** There are many choices for processors on the market, ranging from tabletop units to huge bulky machines. Again assuming low volumes for the master films, a small unit is the most appropriate choice, to say nothing of ease of

shipping. Developing involves aqueous chemistry and a pure water source, and the larger machines require a separate plumbing hookup for the machine. Since the quality of the water supply and subsequent wastewater treatment are questionable in Bamako, a small unit would be best for a young laboratory start-up. Bray manufactures an excellent machine which will accept locally available chemistry; Houston Fearless makes a similar machine which uses a proprietary chemistry and would require continual ordering and shipping of these chemicals.

Densitometer

‘The aim when exposing, processing and duplicating microforms is to achieve consistent results so that each image is easy to read and good quality prints can be produced without adjusting the printer. If all images are of near identical density good results can also be obtained from image scanning with no need for test runs. The density of silver halide images is measured with a densitometer which meters the amount of light transmitted through the material. Clear areas are never perfectly transparent and some light can always pass through the dark areas. A typical standard might call for a background density between 0.9 to 1.1 with negative film and a base fog density in the clear areas below 0.12. For most applications it is best to aim for a background density of around 1.0. To simplify testing it is normal to film test patches at the start of the film to provide large areas from which readings can easily be taken. These can be incorporated within a test target which also includes five or more resolution test charts.

‘Several variables can affect the density of microfilm images, these include the lighting on the camera, the temperature and strength of the developing solution and the length of time that the film is in contact with the developer. Camera lamps produce less light as they age and they should be regularly replaced; processing chemicals require replenishment to ensure consistent results.’

Duplicator

‘Diazo material is sensitive to ultra-violet light but can be handled in daylight. It is exposed by placing it in close contact with a master film and projecting UV light through the master on to the copy film. Areas masked by dark parts of the master are protected from light while those in contact with clear parts of the master are sensitized. To develop the diazo film it is passed through ammonia vapor which causes diazonium salts in the coating of the copy film to couple with other chemicals and form organic dyes in the areas unexposed to UV light. Where UV light has reached the copy film the salts are rendered inert and no dye is formed. Diazo is thus a non-reversing medium and a master negative will produce a negative diazo duplicate.

‘Diazo duplication can be performed in daylight because small quantities of UV light do not affect the film. Unless the duplicator has an internal filtering system, or only moderate volumes of duplicates are produced, it may be necessary to arrange for exhausted ammonia fumes to be vented from the production area. Diazo duplicators for roll formats contain a UV lamp and a transport mechanism to move the copy and

master film in contact through the light beam. The films then separate, the master is re-spooled and the copy film passes into a chamber filled with ammonia gas where the latent images are developed. Diazo copies are less susceptible than silver halide film to damage by dirt, finger marks or scratching as the image is more integral with the film. They are not used for archival applications requiring the maximum possible storage life, but they are certainly reliable for most commercial applications and if protected from long-term exposure to UV light they are suitable for applications requiring storage for up to 50 years.'

There are other types of duplication, namely silver halide and vesicular, but both of these types of film break down at high temperatures and are not meant for significant handling. Therefore, diazo duplicates are the appropriate choice for the Kinkajou. One significant drawback to using diazo film is that it is only available in blue or black tints.

➤ **Recommendation-** Of the duplicators available on the market, those manufactured by Micobra are among the most appropriate for a small micrographics laboratory. They are small in size, extremely lightweight, and designed for low volumes. Their simple layout requires minimal maintenance and, importantly, no ventilation is necessary.

▪ **Equipment costs (camera, developer, densitometer, duplicator, films, chemicals)**
Assuming that all necessary materials are available, equipment costs are the most significant barrier to realizing a laboratory. The worksheet presents sample costs for different types of equipment. The prices listed here are the lowest prices found. Our base estimate for equipment costs is approximately \$12,500.

▪ **Training costs**
The cost of training and paying lab technicians is difficult to estimate. Probably the best source of information was a similar microfilming effort undertaken in Senegal by the Center for Research Libraries (CRL). This was an archiving effort and so had the goal of large-volume filming at excellent quality; duplication was less of a priority. However, all of the production steps were taken, and so it is an instructional model. According to their final report², training and on-site equipment calibration required significant funds and repeated efforts, eventually being paid for by the Government of France. We are currently in contact with representatives from CRL to obtain detailed accounts. However, a rough estimate for their training costs is \$7000, for filming, developing, and duplication. Senegal already had at that time technicians who were familiar with micrographics, so one can only assume that training costs would be higher in Mali where there is no infrastructure or local expertise.

▪ **Labor, Production, and Maintenance costs**
The daily wage for 35mm film technicians in Bamako is approximately US\$6 per day. We would expect that this wage for a micrographics technician to be comparable or slightly higher, considering the specialized equipment and need for training. The cost of blank films, including shipping and assuming bulk orders, is about \$8.30.

We can extrapolate from the CRL case study that the cost of producing a single master of 780 pages in good conditions in West Africa is about \$240. The worksheet presents several different models for on-site production: one only for master copies, one with runs of 250 duplicates for

² See www.crl.edu/areastudies/CAMP/relatedprojects/t6archives.htm.

each master, one with 500 duplicates for each master. In each model, as the number of masters processed increases, the influence of the high capital costs on the cost per master value decreases. Considering the masters-only model, for 50 masters, the cost per master is about \$635. However, when compared to the low cost of US production at \$129 per master (including shipping), it is clear that this scenario is not the most economically efficient. The cost per master for on-site production will continue to decrease as more masters are made. If we expect Kinkajou users to call for microfilm production on the order of 500 masters, then we would expect a cost per master of approximately \$287. However, this level of production seems unlikely at this time.

Maintenance costs are a significant unknown. Routine maintenance such as cleaning and bulb replacements is simple enough and wouldn't require much training. Any breakdown of the main equipment would be much more complex. For the small, highly-engineered units we are recommending, however, spare parts are expensive and would need to be shipped from overseas. The costs of flying in a consultant technician for repairs would be prohibitively high, and local technicians of 35mm machines might not be able to perform repairs. The equipment will certainly require repairs at some point, either routine or due to some malfunction. Given their precision and complexity, the uncertainty regarding repairs is a major detractor from the feasibility of this scenario.

- **Availability of chemicals**

Fortunately, microfilm developing uses very similar chemistries to regular 35mm film developing. According to our field representative in Mali, general chemicals for each step of the developing process are available in Bamako. Most of these chemicals were manufactured in East Asia. However, it would be necessary to verify for any given processor that the proper chemicals and concentrations were available.

- **Environmental hazards and requirements**

Some of the chemicals required for the developing process are toxic and/or require special handling and storage. Chemical exposure is much greater for large, deep-tank developer units than for small, self-contained units. Chemicals that would be available locally are for use with aqueous chemistries; dry-powder chemicals would have to be specially ordered and shipped. Technicians will need to be trained on the normal handling of these chemicals and emergency procedures. Since image and film quality are not the most significant factors in the production of microfilm for this project (durability being the primary factor), environmental controls for a micrographics laboratory in Mali are less stringent than they would be in an archives or library setting. However, chemicals should generally be stored in a cool, dark place, separated by family. Depending on the size of the developer unit, plumbing lines in and out will have to be hooked up and the water quality monitored. Any laboratory will require good ventilation, if not dedicated fans and exhaust. Disposal is also an issue, even though the low volumes would probably not pose an environmental threat. Our field representative is currently exploring the proper procedure for disposal as undertaken by other 35mm film processing facilities in Bamako.

- **Electrical requirements**

Mali runs on 220V, 50 cycles. Almost all of the available micrographics equipment runs on 120V, 50 or 60 cycles, so a transformer or two will be needed. Microfilms need to be developed or duplicated all at once, so if the power cuts out during production, the film will have to be discarded. This may or may not be an issue, depending on the reliability of the electricity supply in Bamako.

- **Shipping costs / times**

This scenario would require as input from abroad the blank films for filming and duplication. The worksheet presents shipping quotes from DHL and FedEx from various locations.

- **Is volume high enough to be self-supporting?**

Since WorldEd is currently the only user of the Kinkajou in Mali, this question of self-sustenance is of serious concern. The dynamics of ordering and cost may determine an appropriate setting for the laboratory.

- If WorldEd remains the only user, it would make sense to house a micrographics laboratory in an INGO office setting, perhaps at the media lab at USAID/Mali. This way, technicians will have other media and project to work on in between microfilm orders.
- If other organizations become interested in the Kinkajou, it may be best to build the lab as a private enterprise in order to avoid conflict regarding possession and priority.

An intriguing possibility is that, with the establishment of a micrographics lab for Kinkajou users, other organizations interested in microfilm may begin to place orders for filming and processing. The most obvious interested parties would be the National Archives and the National Libraries. In the past, the National Libraries seriously considered building microfilming capacity into its facilities, but abandoned the project because it was too costly. If the Kinkajou film lab were able to absorb the capital costs of the equipment and training, it is quite possible that these National institutions would want to make use of the service.

Scenario 3 – Camera, duplicator in Mali; film developed outside

In this scenario, capital and training costs are somewhat reduced and the logistics of setting up a laboratory are greatly simplified compared with the previous scenario. Kinkajou clients would retain the bulk of flexibility associated with a full on-site laboratory, as filming and duplication (the input and output of microfilm production, essentially) would be under their control. However, the long times associated with shipping make this scenario unviable and there is no real advantage in cost per master over the previous scenario.

- **Equipment costs**

We estimate capital costs under this scenario to be approximately \$5200, including the shipping of the equipment from the US or the UK.

- **Training costs**

Based on the CRL case study, where training technicians only in the duplication segment of the production process required significant funds and an outside consultant, that training would still be a major concern. A rough estimate puts the initial cost of training at \$5000.

- **Labor, Production, and Maintenance Costs**

We would not expect a significant change in the labor costs, remaining at \$6 per day. The worksheet presents a model for filming and duplication segments only, which includes the price of shipping both directions. It is difficult to estimate, based on the CRL case study, the price of the filming segment of the process. Since it is much more time-intensive as compared with the developing segment, we would also expect the cost of this segment to be proportionally higher, since we are isolating the capital costs associated with the developer unit. Our analysis reveals that the cost per master after 50 masters under this scenario is \$444, less than in the previous scenario (\$635), but still higher than for outside-only production (\$129).

Maintenance would be somewhat simplified, since there would be one less large machine to service. The camera is the most sensitive piece of equipment and would probably still require the occasional “tune-up”. The high cost of spare parts, repairs, and training, remains a detractor from setting up a micrographics lab under this scenario.

- **Availability of chemicals**

Aqueous ammonia for the duplication process would be the only chemical needed under this scenario. This is readily available in the bazaar in Bamako, although the quality and concentration will need to be tested before use.

- **Environmental hazards and requirements**

Here is where the laboratory logistics are greatly simplified. Ammonia, while it requires some care in handling, is not nearly as toxic as some of the chemicals used in the developing process. Small duplicator units do not require plumbing or even ventilation, though we would recommend *at least* an overhead fan and open windows.

- **Shipping costs / times**

The optimal situation for filming and developing microfilm is when there is a minimal time between the two steps and temperatures are kept low. In high temperatures, exposed silver halide on the film will flip back to the unexposed state, degrading the quality of the image. In a controlled darkroom, this occurs naturally after exposure for about 12 hours and results in a 10% reduction of image quality. In an environment such as Mali, where temperatures are consistently high, this process will be accelerated. Since shipping to an outside service bureau for developing will require about 7-8 business days and the shipping and customs facilities will probably not be air-conditioned, we would expect a significant reduction in image quality during this time. In addition, shipping of the film out of Mali and the finished masters back into Mali will greatly increase the price per master and offset any financial advantage of the reduced capital costs.

Scenario 4 – Only duplicator in Mali; filming, developing outside

In last scenario we consider an on-site laboratory with only duplication capabilities. Filming and developing will be contracted outside, presumably to a firm in the US, and curricula will be sent electronically from Mali. This arrangement cuts down significantly on the capital and training costs. There is decreased flexibility in filming but duplicates can be made at any time, which is important if some reels become damaged. As the decision to print a curriculum onto microfilm is usually planned in advance, the extra time required for shipping the master from the US can easily be taken into account during planning.

- **Equipment costs**

The only piece of equipment necessary under this scenario is the duplicator, which is priced at approximately \$2000.

- **Training Costs**

Since duplication is the least technically complicated of the segment of the production process, we are assuming that the cost for training technicians for this machine will be lower than for the above scenarios. However, it will probably still require an outside consultant, perhaps from neighboring Senegal or from a western micrographics service bureau. There are no firm numbers in the CRL case study for duplication-only training, so our rough estimate is \$2000.

- **Labor, Production, and Maintenance Costs**

In this scenario, the daily wage of the technicians becomes more of a factor, since duplication usually happens in large volumes and requires a significant amount of time. According to inquiries with US firms, the normal throughput per duplicator per day is about 20 films. For

runs of order 1000 films, the difference in price per duplicate from outside production is high, about \$5.50. Therefore, if the number of Kinkajou units in Mali remains in the 1,000-2,000 range, then even on-site duplication is a poor choice from an economic standpoint. However, if the number of Kinkajou units increases to around 10,000, then the price difference per duplicate drops dramatically, to about \$1.90. In this case, the benefits in flexibility of production and economic opportunity discussed above might be enough reason to choose a local duplication laboratory.

- **Availability of Chemicals**

Again, aqueous ammonia is the only chemical necessary under this scenario.

- **Environmental and Disposal Concerns**

Proper ventilation is required. If duplication were to expand to high volumes, a small machine like the Micobra unit recommended above would probably be insufficient. Medium-sized machines like the REAL RB20m can handle more films per day, but require more ammonia and probably better ventilation.

- **Shipping costs / times**

For each film, one master should be kept in the duplication laboratory and one at a storage site, perhaps back in the US. If the duplication master should degrade and wear out, additional master copies could be produced by the service bureau from the original master. Any storage site should have temperature controls and be dark. For these purposes, a box in a closet in an air-conditioned building would be sufficient.

B.4 The Small-Scale User

It is clear from these analyses that it would be economically unfeasible for a local teacher and Kinkajou user to design a lesson or curriculum and have it printed on microfilm for individual use. Shipping makes up a huge portion of the total price for small orders and, unless it is doing significant volume of other business and capital costs have been absorbed, any in-country micrographics bureau will charge even more. An organization would have to place an order of more than 150 films for the price of shipping to be diluted. This is an unreasonable number for a single school system.

C.1 Further considerations

Now that we have examined the feasibility of producing microfilm in Mali, there are many opportunities to broaden this analysis. In particular, we would consider the following:

1. There is no microfilming infrastructure in Mali. Capital costs of building a laboratory from scratch have been significant in our analysis. If the Kinkajou spreads to other parts of the continent, it would be very possible that a regional production center might be a better economic choice than contracting outside. This would hold especially if the center were located in a country such as Nigeria or South Africa where there is already an infrastructure for micrographics.
2. 35mm film infrastructure is present all over the world. While microfilm is more durable than regular 35mm film, it is a specialty film and is priced accordingly. Also, microfilm has been adapted primarily for archiving and data storage, so that equipment and service bureaus are set up to print extremely high-quality film that can last for hundreds of years. We expect the useful life of the microfilms used in Kinkajou units to be around five years, as curricula are normally updated on this period. A typical 16mm x 100ft film can hold up to 10,000 pages. The World Education curriculum for Mali is only ~650 pages, and we do not anticipate significantly higher numbers in the future. For these reasons, microfilm may not be the best choice of medium for the Kinkajou.

It may be beneficial to build a prototype that can handle 35mm film for testing, and also to test different 35mm films for durability. Film length is one drawback, since 35mm film generally holds a maximum of 36 exposures. Considering the World Education curriculum, this would require 18 different films. Perhaps the curriculum could be adapted for modular unit of around this many slides. These would be switched in and out of the projector, causing considerably more wear and tear than a single reel of microfilm. Any redesign should take this into consideration. If prototyping and testing for 35mm films were successful, we would expect that local production would be *much* cheaper than contracting outside of Mali and that turnaround time would be around 1-2 days. This would enable the local teacher or school system to develop individual lesson plans and curricula to use with the Kinkajou, as long as there was the initiative to spend some money on developing the film. Costs for larger organizations like World Education would also be greatly reduced.

3. Another possible area for exploration is alternatives to microfilm for the 16mm format. Up until the early 1990's, 16mm camera film was widely used for recreation and could be bought at the corner drugstore. While this 16mm camera film is no longer commercially manufactured (excepting small companies that slice up 35mm to 16mm size), cameras and film developers still exist in the US for this format. Once we move away from microfilm, prices drop considerably and even open up an avenue for color filming (see below). However, duplication of these films would need to be carefully considered, as would digital-to-film printing. Both of these are possible for slides but their feasibility for whole rolls of film negative is still unclear. Other areas worth consideration are 16mm movie film, which is in wide circulation, and the old 110 B&W film format, which is the same size as 16mm and could be used in the Kinkajou.

C.2 Color Filming

While the Kinkajou was designed for use with bitonal films, several interested parties have expressed a desire to have color content. Color pictures are much more engaging for students and representative of the natural world than are bitonal ones. Teachers of geography and science in particular find color illustrations important for classroom instruction. One difficulty that the Kinkajou may have with color film is a decreased brightness of the projected image. Color film is thicker and absorbs more light than does transparent microfilm. Design that Matters is currently testing the Kinkajou and considering moving to a higher-power LED. The second and more serious difficulty is that the high cost of color microfilming. It is a niche market with only two or three service bureaus in the US, who primarily film maps and important historical documents. Like regular microfilm, color microfilm is rated to last up to 500 years and so is of extremely high quality. A roll costs about \$100 and the chemistry needed to develop it another \$50. Depending on the type of content, filming costs between \$0.75 and \$1.50 per page.³ A master of 780 pages might cost between \$930, almost 25 times the price for a bitonal master. In addition, duplicates cannot be made from color microfilms, so there is no savings associated with bulk production. This places the color option for microfilm firmly out of reach for any conceivable Kinkajou user.

There exist, however, other options for color, including 35mm and 16mm camera and movie film. As discussed above, these can be processed quickly and cheaply almost anywhere in the world and would enable local users of the Kinkajou to create their own curricula. If the Kinkajou design moves away from microfilm, there is no reason not to use color films. Design that Matters is currently researching the process of producing color content and duplicates.

³ Price quotes from Graphic Imaging Technology Inc., Brooklyn, NY

D. Other Possible Kinkajou clients in Africa

Global Village Energy Partnership (GVEP)
International Federation of the Red Cross (www.ifrc.org)
International HIV/AIDS Alliance (www.aidsalliance.org)
Marie Stopes International
Partners in Health (www.pih.org)
Population Services International (www.psi.org, very active in W. Africa)
Reproductive Health Matters
Room to Read (www.roomtoread.org)
Save the Children (www.savethechildren.org)
UNAIDS (www.unaids.org)