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HBCU Technology Transfer Supply Chair Networks' Sustainability: Budget Resource Planning Tool Development

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HBCU TECHNOLOGY TRANSFER SUPPLY CHAIN NETWORKS' SUSTAINABILITY: BUDGET RESOURCE PLANNING TOOL DEVELOPMENT

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Abstract
This study describes the development of a university technology transfer supply chain network sustainability tool that Historically Black Colleges and Universities (HBCUs) can use to become more self-reliant financially. HBCUs lag behind their peer non-HBCUs because historically they have been under-served and were originally established largely as teaching and blue collar trade schools. Increased involvement in research oriented activities such as technology transfer will likely enable HBCUs to grow into new or stronger research institutions. The literature review revealed several problem areas with non-HBCUs university technology transfer include a resource planning issues. These problem areas for non-HBCUs would be challenging for HBCUs as well. Problems with university technology transfer have led to unethical behavior among faculty inventors and university technology transfer specialists at non-HBCUs (C. Hamilton, Schumann, D., 2016). Despite these problems, the non-HBCUs are generating licensing revenues. Systems dynamics is the process of combining the theory, method and philosophy necessary to analyze the behavior of a system in order to provide a common foundation that can be applied whenever it is desired to understand and influence how things change over time. Applying the systems dynamics approach, a budget resource planning tool was developed using a linear programming optimization technique. This study illustrates that classic industrial uses of linear programming optimization techniques can uniquely be used to optimize budget resource planning for sustainable HBCU supply chain networks and other emerging research institutions.

Keywords
budget resource planning, theory of distribution management, social comparison theory, patent licensing, university tech transfer, technology commercialization, HBCUs

Introduction
HBCUs lag behind their peer non-HBCUs because historically they have been under-served and were originally established largely as teaching and blue collar trade schools (Lorenzo L. Esters, 2013; Nia Imani Cantey, 2013). This empirical study seeks to view university technology transfer as a supply chain network for which the theory of distribution management can be applied. Most of the research in supply chain management (SCM) addresses problems from a tactical standpoint. So, a major challenge is to increase research focused on the development of models for the strategic and tactical planning of SCM (Amaro, 2008). Optimization and advanced optimization tools can be developed to address problems with university technology transfer and to level the playing field for HBCUs. When old paradigms lose their effectiveness, one of the reasons leaders do not solve problems right away is the lack of technological tools (Barker, 1992). Advanced supply chain planning addresses a host of decisions about the coordination, design and short term scheduling of supply chain processes (B. M. Fleischmann, Herbert, 2003).

The development of the proposed Budget Resource Planning Tool is important because the literature review revealed that the TTOs need clear goals, priorities, resource planning, and planned investments of their financial resources (Friedman, 2003; Siegel, 2003; Van Hoorebeek, 2004). This is even more imperative for emerging research institutions such as the HBCUs which have more limited resources. Further, TTOs need to be adequately resourced with, for example, adequate legal budget, TTO staff compensation, in-house venture capital program (esp. for medical related inventions), and a business incubator (Degroof, 2004; S. Shane, 2002; S. S. Shane, Toby, 2002; Siegel, 2003).

It costs money to make money. Investments have to be made in providing and managing the necessary resources to operate a technology commercialization program successfully. The proposed Budget Resource Planning Tool is designed with the theoretical framework for research in mind. In particular, it was designed from the viewpoint that university technology transfer is a supply chain network. Five (5) steps were taken to develop the Budget Resource Planning Tool are described and include the:

1. development of the concept model for the university technology transfer supply chain network;
2. development of a licensing revenue optimization model;
3. collection of cost and supply capacity data;
4. experimentation; and
5. model validation.

Theoretical Framework

Theoretical frameworks provide a structure to support explanations for why research problems exist. The problem here is that there is a lack of HBCU engagement in tech transfer. As per the social comparison theory (Festinger, 1954), individuals satisfy their fundamental need for accurate certainty and cognitive limpidness by finding information about the accurate certainty of their opinions and the accuracy of their abilities by sizing themselves up to others (Jerry Suls, 2000). According to Leon Festinger, the need for comparisons to similar others leads to affiliation, pressure toward uniformity in groups, and a unidirectional drive upward that leads to competition. Upward comparisons are with individuals or groups that are believed to be better, and downward comparisons are with those that are believed to be worse off (Abraham P. Buunk, 2007). If a group believes that their own abilities and efforts do not measure up, they may be motivated to make improvements. Thus, HBCUs can learn technology transfer and improve by comparing themselves to non-HBCUs.

Beginning with lessons learned from the social comparison theory, instead of studying what a top ranked well established research university such as Stanford, MIT, University of California Berkeley, University of Illinois-Urbana Champaign or Georgia Tech is doing, this study will focus on what the emerging non-HBCUs are doing with their tech transfer programs. Three (3) of the primary lessons learned from the social comparison theory follows:

1. HBCUs should be compared to non-HBCUs of similar ability and geographic location. With respect to the social comparison of ability, individuals compare themselves with others that have similar abilities (Festinger, 1954). This comparison allows them to lessen their uncertainty and enhance or preserve their self-esteem. These comparisons are based on others who are in close physical proximity because such individuals are likely to be similar in key ways (Greenberg & Ashkanasy, 2007; Suls & Wheeler, 2000). Thus, physical geographic location matters.
2. Competition, cooperation and conforming are social evaluation strategies related to social rules for distributing rewards; and competitive social comparison is greatest when the comparer and other person are similar in ability (Stephen Dakin, 1981).
3. Any comparison needs to be specific with objectively measurable attributes so as to diminish biasness (Allison, 1989; Van Lange, 1991).

These lessons can be used to identify non-HBCU schools for the 24 HBCU doctoral schools to compare themselves to with regard to technology commercialization.

An ideal theoretical framework for researching the phenomenon of HBCUs being woefully behind in technology commercialization should make use of theory integration and theory triangulation. Theoretical integration occurs when two or more theories are joined because the integrated theories work more effectively than any one of the premises alone in explaining the phenomenon. There are examples in cognitive psychodynamic therapy. However, it can be difficult to integrate theories when there are differences in philosophies, ideas, constructs and presumptions (Kock, 2009). Further, theory triangulation is the analysis of data from more than one perspective, hypotheses and/or theories (Ammenwerth, 2003); and it is rarely used (Holloway, 2002). Nevertheless, using theory triangulation and integration, the Social Comparison Theory and Theory of Distribution Management are joined.

The Theory of Distribution Management is a business management theory that states that since institutions are so interlaced, *system dynamics* influences the function of product R&D, promotion and sales (Mentzer, 2001). It is a system dynamics idea applied to production distribution as noted in Forrester's 1961 book *Industrial Dynamics* (Forrester, 1961). System dynamics is the process of combining the theory, method and philosophy necessary to analyze the behavior of a system in order to provide a common foundation that can be applied whenever it is desired to understand and influence how things change over time (Forrester, 1993). The 1958 introduction of the Theory of Distribution Management is believed to be the first instance of a reference to supply chain management (SCM) (Mentzer, 2001). Supply chains are "networks" of three (3) or more organizations involved in downstream and upstream linkages. The supply chain includes value producing activities and processes. The valuables are products and services delivered to consumers that enhance performance (Ketchen, 2008; Kumar, 2001; Mentzer, 2001). The traditional SCM view is to move goods or services in a tactical manner as a cost center. University tech commercialization is a supply chain network because it is comprised of three or more organizations (i.e. the research labs, TTO and industry partners that patented inventions are licensed to) as shown in Exhibit 1. In the university tech commercialization supply chain, the supplies are patented inventions demanded by licensing partners. A network node is a TTO distribution center (TDC), lab, or TTO store. The supply chain can begin with one or more labs and end with one or more TTO stores. The TDC's satisfy TTO stores' and demands from the marketplace.

Exhibit 1. Typical Supply Chain vs. University Tech Transfer Supply Chain Networks

Typical Supply Chain	Tech Transfer Supply Chain
Suppliers	Tech transfer specialists that evaluate inventions
Manufacturing plants	Faculty inventors' research labs
Distribution Centers / Stores	Tech transfer offices (TTOs) as TTO Distribution Centers
Inventory/ Supplies	Invention disclosures, patent applications, patents
Inventory costs	TTO staff labor costs, Legal fees
Customers	Faculty inventors, Industry partners

Supply chains have to be managed because customers demand more value; and advanced computerized planning systems make it possible to manage supplies in order to meet demands. Advanced planning systems include optimization techniques, forecasting and scenario planning that provide what-if analyses and simulation (Kumar, 2001). Best value supply chains provide alignment in the interests of all participants. This alignment can be achieved through collaborative forecasting with suppliers (i.e. in university tech transfer, suppliers are the TTOs) and customers (i.e. industry licensing partners) (Ketchen, 2008).

Very little has been written about tech transfer as a supply chain network. However, product development has been recognized as a fundamental link in the technology supply chain (Tatikonda, 2003). Further, it has been proposed that product tech transfer effectiveness is greatest when companies delicately match the technology types that they want to transfer with their industrial supplier relationships in inter-organizational interactions (Tatikonda, 2003). If tech transfer is viewed from this supply chain lens, the demand for invention disclosure evaluations related to supply chain processes such as the demand forecast methods and demand arrival processes that are dedicated internal resources. In this context, university tech managers are supply chain managers aiming for efficiency to maximize licensing revenues. TTOs are impacted by inventory reduction and fill rates, customers' satisfaction, revenue loss; and the costs for inventory, managing resources are the most significant tasks of a capable supply chain manager. Minimizing the time to evaluate invention disclosures, minimizing costs, and maximizing licensing revenues are issues for TTOs. Interestingly, there is a need for future research in SCM planning and scheduling in process industries (Amaro, 2008; French, 2006). Few supply chain operation scholarly contributions deal with process industries (Amaro, 2008; M. B.-R. Fleischmann, Jacqueline M.; Dekker, Rommert Dekker; van der Laan, Erwin; van Nunen, Jo; Van Wassenhove, Luk, 1997). Thus, university tech transfer supply chains are complex network systems for which modelling and simulation can be used to investigate, find optimal solutions, and predict performance outputs.

Financial resource planning should become a best practice in tech transfer because patenting and marketing to potential industry licenses is very expensive. This is a real problem and balancing act for TTO directors (Silverman, 2007). With each invention disclosure, TTOs must decide whether to invest funds, patent and market the technology quickly or they miss opportunities. A study of TTO directors revealed that 20.3% of the TTOs have to be self-sufficient and fund at least 50% of their operating budgets (Abrams, 2009). Thus, budget resource planning is crucial for all research universities and this is even more crucial an issue for budget strapped HBCUs. The level of resources committed to university tech transfer programs is the greatest determinant of success (Crowell, 2005).

Method

University Tech Transfer Supply Chain Network Concept Model

The first step was the development of the concept model for university technology transfer supply chain network. A concept model for a novel university technology supply chain network. Exhibit 1 provides an analogy between the elements of a typical, traditional supply chain and the proposed tech transfer supply chain network. Exhibit 1 shows a proposed university technology transfer supply chain network. A Supply Chain Network (SCN) is a master operational network involving geographically dispersed resources (Amaro, 2008). In the university tech transfer process, these resources come from geographically dispersed research centers on and off campus. This SCN also involves geographically dispersed market places. In university tech transfer, the geographically dispersed markets are represented by geographically dispersed industry partners. The research labs' faculty inventors submit completed invention disclosure forms to the TTO distribution center. Once inventions are ready for tech commercialization, the TTO distribution center submits the invention to the TTO store. The focus on environmental management and operations has moved from local optimization of environmental factors to consideration of the entire supply chain (Linton, 2007). In case studies, it is useful to examine the supply chain in its entirety (Pagell, 2009). Thus, the entire university technology transfer supply chain is considered herein.

The TTO store and distribution centers are ***Suppliers***. The literature review revealed that 72% of the TTOs have three (3) or fewer full time equivalent (FTE) staff members (Swamidass, 2009). The larger well regarded TTOs have staffs of 4 to 6.5 FTEs per $100 million of extramural research awards (Crowell, 2005). In the university technology transfer supply chain network, each TTO staff person can be a supplier that seeks to meet customer ***Demands***. The TTO staff may pitch patented inventions and travel to the potential industry partners; or these potential customers may come to the TTO store. Thus, their interchange is shown in Exhibit 2 as bidirectional. This is a dense network because each supplier can work to supply each industry partner customer's ***Demands***.

S_i, Suppliers are TTO staff persons

D_j, Industry partner customer demands

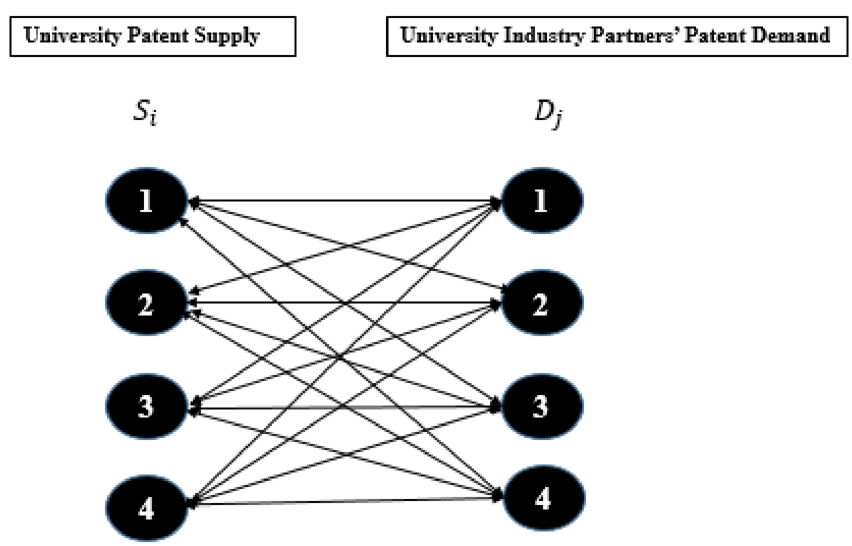
C_j, TTO invention capacity

C_{ij}, Cost that Suppliers i incur when interacting with customers j

x_{ij}, Licensing deals

Common university tech transfer costs include the legal costs of patenting; and the TTO staff labor costs. The TTO staff persons are typically the individuals who work to negotiate licensing deals between their university and the industry partners that are seeking to license university technology. Exhibit 2 illustrates this university tech transfer supply chain network.

Exhibit 2. University Technology Transfer Supply Chain Network



The Classic Warehouse Shipment Transportation Model

In the second step, using the classic supply chain warehouse shipment transportation model, a simple linear programming model was developed to maximize the licensing revenues between suppliers i and customers j in order for TTOs to recuperate licensing costs. The costs include TTO labor and patenting legal fees. Before explaining the method used to develop a linear programming optimization tool to maximize university technology licensing revenues between the Suppliers i to the Customers j (i.e. Industry Partners) with Demands Dj, an explanation of the classic warehouse shipment transportation model is necessary. The classic supply chain warehouse shipment transportation model can be solved with Excel Solver as illustrated in Exhibit 3. Here are the variables in the Classic Transportation problem (Millar, 2013):

F_i – Fixed Costs
S_i – Supply
D_j – Demand from each customer
X_{ij} – the amount shipped from i to j
(i.e. from supplier i to customer j)
M = a large value = S_i
C_{ij} = unit transportation cost from i to j

Exhibit 3. Classic Warehouse Shipment Transportation Network Design Problem in Supply Chain Management

	COSTS	CUSTOMER A	CUSTOMER B	CUSTOMER C	CUSTOMER D	SUPPLY from each warehouse
①	WAREHOUSE 1	0.6	0.56	0.22	0.4	10000
②	WAREHOUSE 2	0.36	0.3	0.28	0.58	15000
③	WAREHOUSE 3	0.65	0.68	0.55	0.42	15000
④	DEMAND	8000	10000	12000	9000	
	SHIPMENTS	CUSTOMER A	CUSTOMER B	CUSTOMER C	CUSTOMER D	Row totals
⑤	WAREHOUSE 1	0	0	10000	0	10000
⑥	WAREHOUSE 2	5000	10000	0	0	15000
⑦	WAREHOUSE 3	3000	0	2000	9000	14000
⑧	Column Totals	8000	10000	12000	9000	
⑨	Total cost	$13,830				

Source: (Millar, 2013)

The objective function is to minimize the transportation costs:

$$\text{Min} \sum_i \sum_j Cij\ Xij + \sum_i Fi\ Yi \tag{1}$$

s.t. the following constraints:

$$\sum_i Xij \geq D_j \tag{2}$$

(i.e. amounts to be shipped from i to j need to be greater than the demand)

$$\sum_j Xij \leq S_i \tag{3}$$

(i.e. amounts to be shipped from i to j need to be less than or equal to supplies)

$$\sum_j Xij - M\ Y_i \leq 0 \tag{4}$$

(i.e. if this is positive, this logical constraint, the M Y_i must be positive and Y_i must be equal to one)

$$X_{ij} \geq 0 \tag{5}$$

$$Y_i \in (0,1) \tag{6}$$

1 if the warehouse is opened and 0 otherwise.

Rows 1, 2 and 3 in Exhibit 3 above contains transportation cost data for shipping supplies from Warehouses (i) 1, 2 and 3 to their destinations. The destinations are the Customers (j) A, B, C and D denoted by the columns in Exhibit 3. The upper matrix simply supplies the cost information. For example, cell A1 = $0.6 to ship supplies from Warehouse 1 to Customer A. The Supply column in the upper matrix provides the supply from each of the Warehouses. So, for example, Warehouse 1 can supply 10,000 units. The Demand row in the upper matrix provides each of the Customer's supply demands. For example, Customer A wants 8,000 units.

This linear programming model is a decision support optimization tool commonly used in supply chain management. The decisions to be made are located in the lower matrix denoted by rows 5, 6 and 7 for the three Warehouses and columns A, B, C, and D for the four Customers. The decision to be made is how much supply to ship from each Warehouse to each Customer. This problem is solved using Excel Solver and provides an optimal solution based on a Simplex linear programming algorithm. In Excel Solver, the total cost of shipments to all of the Customers from all of the Warehouses is minimized by changing the values of the cells in the lower matrix of Exhibit 3. The Customer demands satisfied are computed and entered into Row 9. The row totals for the Warehouses rows 5, 6 and 7 are also computed and represent the amount shipped out of each Warehouse and received by the Customers.

Next, the constraints were specified in Excel Solver. The goal is to make sure that the amount received by the Customers is equal to or more than what is actually demanded. Recall that the Customer demand totals are in Exhibit 3, Row 4. The total shipment amounts must be less than or equal to the amount of supply that is available. Lastly, unconstrained variables are made non-negative because a negative amount cannot be shipped. The Excel Solver solution is provided in Exhibit 3. See cells A, B, C and D and rows 5, 6 and 7. The total minimized cost is provided in row 9. Next, an explanation of how this can be used in technology licensing is provided.

Using the Classic Warehouse Shipment Transportation Model in Tech Licensing

The next step was to make use of the Classic Warehouse Shipment Transportation Model in the tech licensing arena. Using the aforementioned classic supply chain warehouse transportation problem example, a similar linear programming optimization tool was developed with the purpose of maximizing patent licensing revenues in order to recuperate patenting and TTO staff labor costs. The patent licensing of university technology is between the Suppliers i (i.e. TTO staff licensing specialists) to the Customers j (i.e. Industry Partners) as follows:

S_i, Supplies are patented invention licensing deals

D_j, Customer demands

C_{ij}, Cost that Suppliers i incur when licensing the patented inventions to customers j

x_{ij}, Amount of patented invention licensing deals to be licensed between Supplier i and Customers j

$$\text{Max} \sum_i \sum_j \text{Cij Xij} \tag{7}$$

s.t. the following constraints:

$$\sum_i \text{Xij} \geq D_j \tag{8}$$

(i.e. amounts of patented inventions to be licensed from i to j need to be greater than the demand)

$$\sum_j \text{Xij} \leq S_i \tag{9}$$

(i.e. amounts of patented inventions to be licensed from i to j need to be less than or equal to supplies)

$$X_{ij} \geq 0 \tag{10}$$

The third step was the collection of cost and supply capacity data. The social comparison theory teaches that entities are most likely to emulate other entities that are in the same geographic location and that are of similar ability (Festinger, 1954). Applying the social comparison theory, nine (9) non-HBCU schools were identified and selected that HBCUs can emulate. Here, ability is based on licensing revenue generation. The selected non-HBCUs are non-HBCUs in the lowest quartile of licensing revenues reported in the Association of University Technology Managers (AUTM) annual licensing survey.

Using a list of select non-HBCUs, data was collected from the years 2010-2014 about legal expenditures, staff sizes, and total licensing deals from the AUTM database. In addition, salary information was collected from the US Department of Labor's Bureau of Labor Statistics database; and the number of patents was collected from the US Patent and Trademark Office (USPTO) patents database. The cost and supply data is comprised of the mean values for the non-HBCUs' legal fees, estimated labor expenses, and total number of patented inventions in inventory. The legal fees and labor expenses were summed to provide a total expense. This cost information provides evidence of what a licensing deal between a supplier and customer will likely cost.

The fourth step was experimentation. The cost and supply data for the select non-HBCUs was inputted into the budget resource planning tool linear programming model for experimentation. The mean total expense was divided among the three (3) hypothetical TTO staff persons who serve as suppliers; and among their 12 hypothetical customers who are the potential licensees. This value was entered as cost data the Microsoft Excel Solver linear programming optimization tool. The mean value of the total patented inventions owned by the non-HBCUs was also divided between the three (3) TTO staff suppliers. This value was used as patent inventory. A benchmark for the number of licensing deals was used for the total demand from customers. The customer demands are defined by the number of patented inventions customers are willing to license per year. Each customer would typically license one patented invention. Alternatively, the customer demands can be defined in terms of the amount of money they are willing to invest in a licensing deal. Microsoft Excel Solver was used to compute the optimum number of licensing deals given the objective of maximizing the TTO supplier revenue in an effort to recuperate patenting and TTO labor costs.

The last, fifth step was model validation. There are several approaches to model validation. In this study, model validation was achieved with a *scenario analysis* to depict the proposed model's feasibility. With scenario analyses, an example project is used to assess the model's capability and to validate the proposed model (Liu, 2007). Further, in the linear programming optimal solution may be unbounded or infeasible; multiple solutions may be found; or there might be degeneracy. The following steps are criteria that can be used to validate the model (Arsham, 2016):

- If unbounded, to resolve there must be a check on the formulation of the constraints to see if one or more constraints are missing or mis-specified.
- If there are multiple optimal solutions, to resolve, the coefficients in the objective function and the constraint need to be checked. Also, there could have been rounding errors.
- If there is no solution, the model may need to be reformulated after checking the constraints' formulations to see if there are missing or mis-specified constraints.
- In addition, the sensitivity ranges for linear programming problems may be computed.

An experiment was conducted involving use of the Microsoft Excel Solver Simplex LP optimization tool to compute the optimal number of inventions to licenses to each customer with the objective to maximize licensing revenues. The results of the experimentation are presented next.

Results

One (1) experiment was conducted. First, three (3) lessons from Social Comparison Theory research were applied. First, HBCUs should be compared to non-HBCUs of similar ability and geographic location. With respect to the social comparison of ability, individuals compare themselves with others that have similar abilities (Festinger, 1954). This comparison allows them to lessen their uncertainty and enhance or preserve their self-esteem. These comparisons are based on others who are in close physical proximity because such individuals are likely to be similar in key ways (Greenberg & Ashkanasy, 2007; Suls & Wheeler, 2000). Thus, physical geographic location matters. Second, competition, cooperation and conforming are social evaluation strategies related to social rules for distributing rewards; and competitive social comparison is greatest when the comparer and other person are similar in ability (Stephen Dakin, 1981). Third, any comparison needs to be specific with objectively measurable attributes so as to diminish biasness (Allison, 1989; Van Lange, 1991). From these lessons, the nine (9) non-HBCUs were chosen for the HBCUs to compare themselves to include: (1) Baylor University; (2) Georgia Regents Health Sciences, (3) Medical University of South Carolina, (4) Wake Forest University, (5) University of North Texas, (6) Eastern Virginia Medical School (EVMS), (7) Rice University, (8) University of Alabama Huntsville, and (9) Louisiana Tech.

The experiment uses linear programming decision support optimization tool commonly used in supply chain management. Using the Microsoft Excel Solver's Simplex LP optimization tool, the optimal number of inventions to license to each customer is computed with an objective function that serves to minimize costs subject to the following constraints:

S_i, Supplies are patented invention licensing deals
D_j, Customer demands
C_{ij}, Cost that Suppliers i incur when licensing the patented inventions to customers j
x_{ij}, Amount of patented invention licensing deals to be licensed between Supplier i and Customers j

$$\text{Max } Z = \sum_i \sum_j \text{Cij Xij} \tag{11}$$

s.t. the following constraints:

$$\sum_i \text{Xij} \geq D_j \tag{12}$$

(i.e. amounts of patented inventions to be licensed from i to j need to be greater than the demand)

$$\sum_j \text{Xij} \leq S_i \tag{13}$$

(i.e. amounts of patented inventions to be licensed from i to j need to be less than or equal to supplies)

$$X_{ij} \geq 0 \tag{14}$$

In addition, based on AUTM licensing data collected on the nine (9) select non-HBUs, each supplier (i.e. licensing specialist) would realistic not close more than 5 deals per year.

With regard to cost and supply capacity data, the patenting and licensing costs are legal expenditures that are reported in the AUTM annual licensing survey (AUTM, 2013). The TTO staff size as FTEs is provided in the AUTM annual licensing survey. Here, the licensing staff FTEs were used. Staff labor expenses was calculated as the product of the annual salaries and the full time equivalents. The US Department of Labor, Bureau of Labor Statistics wage data by state was used for annual salaries in legal occupations. Legal occupation salaries were chosen since they are more conservative estimates as they are higher than salaries such as for marketing and sales professionals which are also relevant to tech licensing. The legal occupation salaries follow (US Department of Labor, 2013): (1) Baylor College of Medicine, TX, $100,760; (2) Georgia Regents University, GA, $97,670; (3) Medical Univ. of South Carolina, SC, $74,940; (4) Wake Forest University, NC, $85,650; (5) University of North Texas Health Science Center, TX, $100,760; (6) Eastern Virginia Medical School, VA, $101,500; (7) Rice University, TX, $100,760; (8) University of AL Huntsville, AL, $83,950; and (9) Louisiana Tech, LA, $81,250.

The number of inventions provide supply capacity and a gross count of the number of patents that the universities owned was used. This data comes from the USPTO Patent Full-Text database (PatFT) (USPTO, 2016). The PatFT was used to search for all occurrences whereby each non-HBCU is listed as an assignee (i.e. owner) by name. Using these amounts of patents assumes that any prior licenses are non-exclusive licenses and these inventions are still available for future licensing opportunities. Of course, in reality, these non-HBCUs may have entered into exclusive or non-exclusive licensing deals. Exhibit 4 provides the results of the experiment. The mean total expense of $1,154,163 was divided among the three (3) hypothetical TTO staff persons who serve as suppliers; and among their 12 hypothetical customers who are the potential licensees. Thus, the value $1,154,163/36 = $32,060 was entered as cost data in each of the upper matrix cells of Exhibit 4 for the Microsoft Excel Solver linear programming optimization exercise.

Exhibit 4. Results of Experiment

		CUSTOMER A	B	C	D	E	F	G	H	I	J	K	L	SUPPLY OF PATENTS
①	SUPPLIER 1	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	15
②	SUPPLIER 2	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	10
③	SUPPLIER 3	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	$32,060	40
④	DEMAND	1	1	1	1	1	1	1	1	1	1	1	1	
	Licensing Deals	**CUSTOMER A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**Column totals**
⑤	SUPPLIER 1	2	1	0	0	0	2	0	2	2	2	2	2	15
⑥	SUPPLIER 2	0	0	0	0	2	2	0	2	0	2	2	0	10
⑦	SUPPLIER 3	2	2	2	2	2	2	2	2	2	2	2	2	24
⑧	Row Totals	4	3	2	2	4	6	2	6	4	6	6	4	49
⑨	Maximum Total Revenue to recuperate licensing costs	$1,635,060												

The mean value of 65 total patented inventions was also divided between the three (3) TTO staff suppliers. Typically, in a TTO, the three (3) licensing specialists will be responsible for managing a patent portfolio of a subject matter within the specialist's expertise. So, in this experiment, Supplier 1 manages 15 biotech patents, Supplier 2 manages 10 software patents, and Suppler 3 manages 40 pharmaceutical patents. In this exercise, the demand was set at 12. The goal is for each Supplier to close one deal each month. The values shown in the lower matrix of Exhibit 4 are the results of the Microsoft Excel Solver optimized solution for maximizing the patent licensing revenues while meeting customer demands and other constraints. The goal is to recuperate the TTO's labor and patenting legal costs.

The Excel Solver solution is provided in Exhibit 4. Rows 1, 2 and 3 contains licensing cost data for licensing from the TTO licensing specialists herein called Suppliers (i) 1, 2 and 3 to the Customer destinations. The destinations are the Customers (j) denoted by the columns A to L. The upper matrix simply supplies the cost information. For example, cell A1 = $32,060 to license supplies of patented inventions from Supplier 1 to Customer A. The Supply column in the upper matrix provides the supply in terms of amount of patented inventions that each Supplier is responsible for licensing. So, for example, Supplier 1 can potentially supply 15 patented inventions to Customers. The Demand row 4 in the upper matrix provides each of the Customer's supply demands. For example, Customer A wants to license one (1) patented invention.

The decisions to be made are located in the lower matrix denoted by rows 5, 6 and 7 for the three (3) TTO Suppliers and columns A through L for the 12 Customers. The decision to be made is how much supply of patented inventions to license from each Supplier to each Customer. This problem is solved using Excel Solver and provides an optimal solution based on a Simplex linear programming algorithm. In Excel Solver, the total licensing revenues from all of the Customers from all of the Suppliers is maximized by changing the values of the cells in the lower matrix of Exhibit 4. The Customer demands for patented inventions satisfied are computed and entered into Row 9. The row totals for the Suppliers rows 5, 6 and 7 are also computed and represent the amount licensed out of each Suppliers' supply of patented inventions and received by the Customers. Next, the constraints are specified in Excel Solver. The goal is to make sure that the amount received by the Customers is equal to or more than what is actually demanded. Recall that the Customer demand totals are in Exhibit 4, Row 4. The total amounts of patents to be licensed must be less than or equal to the amount of supply of patented inventions that are available. Lastly, unconstrained variables are made non-negative because a negative amount cannot be licensed. See cells A, B, C and D and rows 5, 6 and 7. The total maximized licensing revenues is provided in row 9. This will enable the HBCU to plan its labor resources (i.e. the use of its TTO licensing staff suppliers) in order to recuperate their labor costs and patenting legal fees.

Conclusion

Financial resource planning is a best practice in tech transfer. The traditional supply chain network from product manufacturing to customer sales and support is not the same as for the proposed university technology transfer supply chain network and its required distribution management. The primary difference is that in the traditional supply chain network, there is typically mass production and mass sales volumes in a steady stream of supply and demand that needs to be managed. However, on the contrary, in the university technology transfer supply chain, there are occasional transfers of patent products (Tatikonda, 2003).

With regard to the novel view of university tech transfer as a supply chain network, budget resource planning using the proposed linear programming optimization tool is a viable way toward sustainability of university technology transfer supply chain networks. Use of budget resource planning can be tested with future research to measure the development and sustainability of HBCU tech transfer supply chain networks. Patenting and marketing to potential industry licenses is very expensive. This is a real problem and balancing act for TTO directors (Silverman, 2007). With each invention disclosure, TTOs must decide whether to invest funds, patent and market the technology quickly or they miss opportunities. A study of TTO directors revealed that 20.3% of the TTOs have to be self-sufficient and fund at least 50% of their operating budgets (Abrams, 2009). Thus, budget resource planning is crucial for all research universities and this is even more crucial an issue for budget strapped HBCUs. The level of resources committed to university tech transfer programs is the greatest determinant of success (Crowell, 2005). This study illustrates that classic industrial uses of linear programming optimization techniques can uniquely be used to optimize budget resource planning for sustainable HBCU supply chain networks. It is also applicable to other emerging research institutions.

Optimization and advanced optimization tools can be developed to address problems with university technology transfer and to level the playing field for HBCUs. This novel budget resource planning tool will enable the HBCU to plan its labor resources (i.e. the use of its TTO licensing staff suppliers) in order to recuperate their labor costs and patenting legal fees. This tool is valuable for any emerging research institution in the public or private sector. New start up firms have emerging research operations. Private engineering, biotech and pharmaceutical firms with newly established R&D tech commercialization units can also benefit from the use of this resource optimization tool.

Author's Biography

Clovia Hamilton earned a PhD in Industrial & Systems Engineering with a concentration in Engineering Management from the University of TN Knoxville in August 2016. Prior to that she earned a JD from Atlanta's John Marshall Law School, a Master of Laws (LLM) degree in Intellectual Property law from the University of IL at Urbana Champaign and a MBA from Wesleyan College. Clovia is a former USPTO patent examiner and she is a registered patent attorney. She is s subject matter expert in university technology transfer, entrepreneurial business development and government contracting. She has served as the Director of Intellectual Property and Research Compliance at Old Dominion University and as a technology transfer specialist for the University of IL at Urbana Champaign and the EPA's National Vehicle Fuel Emissions Lab. Dr. Hamilton has also taught business and engineering law and ethics as an adjunct professor and lecturer since 2005.

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