Theory of Constraints To Improve Labor Productivity. Study Case In Santo Domingo, Ecuador

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Abstract

The aim of this paper focuses on the management of physical restraints to improve labor productivity indicators in a small manufacturing company of Santo Domingo de los Tsáchilas. To achieve this objective a procedure with a holistic character that contributes to the identification, subordination and exploitation integrally of physical constraints of the system under study was designed. Among the major findings: the existence of interruptions in operations P2 and P5, which decreases the total production capacity; the presence of a bottleneck in the operation (P1) "Preparation to Print". These aspects allowed in conjugation with economic elements, the approach of four production strategies, suggesting the implementation of the third strategy, generating an impact of more than four thousand US dollars a year and market coverage of 96%, achieving an important balance between production indicators, earnings and market shares.

Keywords: Theory of Constraints, Work Organization, Physical Restraints, Labor Productivity, Production Management.

1. INTRODUCTION

The need to study the most effective mechanisms to optimize resources and increase production levels and customer services at the enterprise level, it is admittedly important, which include authors such as De Miguel Guzmán [6], Fernández García [7], Maynard [16], Pérez Pravia [17], Salvendy [22], Martínez Vivar, Sánchez Rodríguez, García Vidal & Pérez Campdesuñer [15], who have somehow made contributions to the development of this science work.

An interesting solution proposal that emerges in this context is the Theory of Constraints (TOC) created by the iraeli physicist Eliyahu M. Goldratt, its theoretical proposal is essentially in charge of developing actions carried out on those few elements that prevent a company improve in relation to its stated goal (Goldratt & Cox [9]); the theory has had several followers from around the world (Abisambra Lemus & Mantilla Cuadros [1], Aguilera [2], Aliaga Palomino [3], García Vidal [8], Gómez [10], González Gómez, Ortegón Mosquera & Rivera Cadavid [11], González &

Escobar [12], Leon, Cardeñosa & Pravia [14], Villagómez, Viteri & Medina [24], Barausse, Yunes & Chamberlain [5], Puche et al. [20]). The authors cited divided for analysis restrictions under management in two areas: the political and physical. The management of physical restraints (MFR) is aimed at increasing the efficiency and effectiveness of resource flows, hence the importance for the analysis of productivity at work, focusing on finding and supporting the main limiting factor, which in the description of this theory are called constraints or "bottlenecks".

In empirical studies previously developed in the Digital Printing of Santo Domingo they have demonstrated the following problems:

- Lack of knowledge of the structure of production flow and your organization for process performance.
- Lack of physical constraints in the production process.
- Lack of funds structure working times for operations.
- Lack of indicators of achievement of the working day, while there are no established time standards and performance.
- Lack of productive strategies and their subordination to economic factors.

Both theoretical and practical that demonstrate the need to design a process that contributes to the management of the physical restrictions on Digital Printing of Santo Domingo, which determines the research objective aspects.

1.1 The Theory of Restrictions and Increased Productivity

As a systematic philosophy of improvement, the TOC is based on three basic premises: (a) every system has a goal and the same is achieved if certain conditions are met, (b) the performance of the system as a whole is more than the sum the individual performances of its component parts and (c) only very few elements, sometimes only one, limit the performance of a system in a historical context given (Pesic, Andelkovic & Dasic [18], Reid [21], Schragenheim & Dettmer [23]).

Based on the precepts of the TOC the following principles (Anderson [4], Gupta, Ko & Min [13], Pérez Pravia [17], Pesic, Andelkovic & Dasic [18]) are as follows:

- The ability of a system should not be balanced because the system is oriented towards the balance of the flow, not capacity;
- The level of use is a resource bottleneck is not determined by some other restrictions in the system.
- The time lost in a bottleneck is equal to the time lost throughout the system;
- No need to make maximum use of resources, as only maximum utilization of resources with those restrictions is desirable;
- If a resource is not considered a restriction should not be used more than allow those restrictions.
- The customer value is not generated in a particular place within the system, but in the whole system.

In the case of this work it will work with one of two types of restrictions, physical restrictions understood as one element of the logistics system whose capacity is less and (or) its cycle is greater than what is demanded to meet the objectives end system, these restrictions are usually: the market, manufacturing or service and the availability of raw material. To work with these restrictions has continued to work as a general methodology the following steps (Goldratt & Cox [9], Gupta, Ko & Min [13], Pretorius [19], Reid [21]):

1. Identify the system constraints: means finding the points, the resources are not sufficient, in order to define to what extent these limit the overall system performance. This step takes into account three principles: a) The number of restrictions is extremely limited; b) No waste using a restriction; and c) should appreciate the value of the magnitude of the impact of restrictions on the organization.

2. Decide how to exploit the system constraints: it aims to achieve the greatest possible benefit for the organization, on the premise of not wasting limitation; the restrictions should not fill what limitation should or need to consume, but no more;
3. Subordinate else to the above decision: the subordination defines the roll of the operations are not limited. Its purpose is to protect all decisions relating to the operation of limitations during daily operations, ie in this space must open system constraints;
4. Elevate the system constraints: it means that it is time to lift the restrictions;
5. If you have broken the limitation, return to step 1.

These five steps are aimed at ensuring that management attention is focused on what is really important to system performance.

2. METHODOLOGY

For the development of this research a combination of instruments which include direct observation, survey tools and work organization is used. The data processing is developed for the case of the surveys to measure the level of reliability of the scale the Cronbach's alpha coefficient is used and processing is done by descriptive statistics for univariate analysis. Just as data processing process from the tools to balance processes, analysis of jobs, all under the management approach of physical restraints for productive analysis.

The phases of the specific methodology used are:

I. Phase 1. Initial preparation. It aims to ensure the participation and collaboration of senior management and workers in the various tasks to be performed.
II. Phase 2. Familiarization. In order to characterize the organization under study.
III. Phase 3. Analysis of the elements of work organization. Its aim is to diagnose the elements of work organization. To make the diagnosis of work organization, it is decided by the expert group, to which one or more processes must be studied. It is recommended to start the study of the key processes, since they determine compliance with organizational objectives.
IV. Phase 4. Adjustment of organizational and technical measures to improve the elements of work organization in the selected process. Whose goal is to develop measures to ensure the use of productive increases in the process under study.

3. RESULTS

Phase 1. Initial Preparation

At this stage the conditions for the practical development of research were prepared, achieving the team selection, training and communication actions to develop the areas involved.

Step 1. Selection of the working team. In keeping with the nature of research to develop, as well as the information necessary for the development of the study, it was decided to select as part of the team to: Manager, responsible for human talent and responsible for production. With which several meetings were held to explain the intentions of the study and the techniques employed.

Step 2. Training team. In conjunction with the selected work team, two training workshops were developed in order to explain the procedure to be used and its practical usefulness and possible outcomes to be achieved.

Step 3. Provide information to employees developing the study. After forming the team proceeded to report on the study to the productive areas of the printing press, which it did through socialization at a general meeting with the workers, so it is intended that all members of the organization may participate in research and to contribute ideas for improving existing problems and provide possible solutions to them.

Phase 2. Familiarization

Step 4. Characterization of the organization. Digital Printing was established in the City of Santo Domingo de los Tsáchilas in July 25, 2008; in order to break the monopoly at the level of graphic design in the city, since at that time there were only two similar companies which were not sufficient to cover the high demand for printing and services that the community needed in a city with tremendous growth.

Step 5. Analysis of organizational processes. When asked about the existence of organizational processes, one can assert that senior management has not clearly to define them, so that at present organizational processes are not defined. This determined the need to apply the technique of critical examination in conjunction with brainstorming to make a list and diagnosis of the processes taking place in the press from the following three levels: strategic, operational and support processes. After several rounds of job design process map of the organization was achieved.

Phase 3. Analysis of the Elements of Work Organization

In this phase the selection was developed assortments and processes to analyze, which responded to the indicator of sales for the period under investigation.

Step 6. Determine the nomenclature (Assorted) to study. Through Pareto technique using the SPSS version 21.0, assortments occurring in the operating process of printing analyzed. Quantity indicators taken into consideration in production volume and income from sales prices of 2015. According to the results of processing, the selection of products linked concludes with labels, triptychs, stickers and gigantographies, which representing 20% of the products that generate 80% of production and income respectively.

Step 7. Determine the plan or demand for each nomenclature (Ni). For the development of forecast demand for each type of assortment, took into consideration the regime of orders placed for 2015. The data obtained was developed with the WQSB version 4.1 data processing software, using the mathematical method linear regression for a variable. After the processing performed by each variety, the demand forecast 2016 should behave as shown in Table 1.

Products	J	F	M	A	M	J	J	A	S	O	N	D
Labels	5,902	5,989	6,077	6,164	6,552	6,339	6,426	6,514	6,601	6,688	6,776	6,864
Triptychs	1,187	1,137	1,087	1,038	989	940	891	841	792	743	694	645
Stickers	1,173	1,146	1,119	1,092	1,066	1,039	1,012	986	959	932	905	879
Giganto-graphies	88	88	88	88	88	88	88	88	88	88	88	88

TABLE 1: Forecast Demand 2016.

Step 8. Description of the selected process. In the store quality control of raw materials is carried following:

- Raw material (RM) 1: Ink CMYK (4 colors)
- Raw material 2: Paper couche
- Raw material 3: Canvas
- Raw material 4: Aluminium plates
- Raw material 5: Boxes
- Raw material 6: Tape
- Raw material 7: Kraft Papert

Operation 1. Preparation of Print (P1): Among the products that generate higher revenue in the company such as labels, stickers, triptychs and gigantographies, the same sequence of activities is generated before reaching the purely production processes, which they are: a) data collection;

b) Design; c) Design review; d) Waiting time; e) Arrangements design; f) Approval of the design; and g) Send to produce aluminum plate design (except gigantographies).

Operation 2. Printing (P2): In the process of printing the request of the RM1, RM2, RM3, and RM4 is generated to successfully do so; your plotter machine uses for gigantographies and GTO machine for labels, stickers and triptychs, with the collaboration of one worker on each machine used, the process or build if necessary twice in the production of a product.

Operation 3. Drying (P3): In the drying process is performed naturally or if necessary with the help of a fan, which is generated or twice in the production of a product need not intervene no worker.

Operation 4. Cut (P4): After printing and drying process, the cutting process is performed for which the cutting machine, stiletto or turn is required is sent to the city of Quito where it is made a special court (labels-stickers), involving one worker.

Operation 5. Package (P5): This is the final process takes place in which it is required RM5, RM6 and RM7 in order to have the finished product ready to deliver to the customer, one worker intervenes.

Step 9. Determine spending unit time (Tij hours per items). For the development of this step diagrams OTIDA were identified for each variety by independent observations from the development of productive flows under study. Subsequently they process resulting homogeneous matching for each range data obtained Table 2 were pooled.

Products	**Homogenizing processes** (hours/item)				
	P1	**P2**	**P3**	**P4**	**P5**
Labels-Stickers	0.04	0.033	0.04	0.04	0.012
Triptychs	0.057	0.09	0.05	0.04	0.13
Gigantographies	0.016	0.20	0.10	0.10	0.10

TABLE 2: Tij (hours for ítem).

Step 10. Determine the Productive Fund Available (hours per year). The labor of printing is 24 working days per month with one shift a day full 8 hours being worked each year a total of 332 days: to determine the productive fund available the following data were obtained. Preventative maintenance is done twice a year, consuming a total of two working days. 15 days holiday a year are granted. Furthermore it is known from historical records of previous years lost an average of 50 hours a year for lack of electricity and 62 hours of casual interruptions breaks for operations P2 and P4, respectively. Similarly became known through a sampling instant feedback that the use of working hours for operations P1 and P5 is 85%, the loss of time that cause this behavior are associated with indiscipline in the workday, as fundamental. Finally, the information is summarized in Table 3.

Equipment / Workers	**Quantity**	**Value of equipment**
P1	2 equipment	2,500 $/eq
P2	2 equipment	8,000 $/eq
P3	2 equipment	600 $/eq
P4	2 equipment	2,000 $/eq
P5	2 equipment	1,200 $/eq

TABLE 3: Production Available Fund (PAF).

With previous data funds available production time (PAF) for each process were determined,

obtaining the results in Tables 4, 5, 6, 7 and 8:

TPF p1	332 d/y* 24 h/d-eq*2eq	15,936 h/y
TPF p2	332 d/y* 24 h/d-eq*2eq	15,936 h/y
TPF p3	332 d/y* 24 h/d-eq*2eq	15,936 h/y
TPF p4	332 d/y* 24 h/d-eq*2eq	15,936 h/y
TPF p5	332 d/y* 24 h/d-eq*2eq	15,936 h/y

TABLE 4: TPF (Total Productive Fund). Note**:** d: days; y: year; eq: equipment; h: hours.

TRF p1	16 h/y* 2eq	32 h/y
TRF p2	16 h/y* 2eq	32 h/y
TRF p3	16 h/y* 2eq	32 h/y
TRF p4	16 h/y* 2eq	32 h/y
TRF p5	16 h/y* 2eq	32 h/y

TABLE 5: TRF (Technological Requirements Fund).

LRF p1	332d/y*16h/d-eq*2eq + 15d/y*8h/d-eq*2eq	10,864 h/y
LRF p2	332d/y*16h/d-eq*2eq + 15d/y*8h/d-eq*2eq	10,864 h/y
LRF p3	332d/y*16h/d-eq*2eq + 15d/y*8h/d-eq*2eq	10,864 h/y
LRF p4	332d/y*16h/d-eq*2eq + 15d/y*8h/d-eq*2eq	10,864 h/y
LRF p5	332d/y*16h/d-eq*2eq + 15d/y*8h/d-eq*2eq	10,864 h/y

TABLE 6: LRF (Labor Requirements Fund).

OCF p1	15% del PAF	756 h/y
OCF p2	112 h/y	112 h/y
OCF p3	0	0
OCF p4	112 h/y	112 h/y
OCF p5	15% del PAF	756 h/y

TABLE 7: OCF (Other Causes Fund).

PAFp1	15,936 h/y- 32 h/y- 10,864 h/y-756 h/y	4,284 h/y
PAFp2	15,936 h/y- 32 h/y- 10,864 h/y-112 h/y	4,928 h/y
PAFp3	15,936 h/y- 32 h/y- 10,864 h/y	5,040 h/y
PAFp4	15,936 h/y- 32 h/y- 10,864 h/y-112 h/y	4,928 h/y
PAFp5	15,936 h/y- 32 h/y- 10,864 h/y-756 h/y	4,284 h/y

TABLE 8: PAF (Productive Available Fund).

Step 11. Analysis of productive capacity available (PCA). To determine the available production capacity of printing, balancing production lines used from the heterogeneous approach, just as the loss capacity coefficient (LKC) and the percent utilization of installed capacity (%UC) was determined, obtaining the results of Table 9.

Products	Demand	P1		P2		P3		P4		P5	
		tij	Qij	tij	Qij	tij	Qij	tij	Qij	tij	Qij
Labels-Stikers	89,200	0.04	3,568	0.033	2943.6	0.04	3,568	0.04	3,568	0.012	1070.4
Triptychs	10,984	0.057	626.09	0.09	988.56	0.05	549.2	0.04	439.36	0.13	1427.9
Gigantographies	1,056	0.016	16.89	0.20	211.2	0.10	105.6	0.10	105.6	0.10	105.6
Roj		0.95		0.95		0.95		0.95		0.95	
PAF		4,284		4,928		5,040		4,928		4,284	
PAF*Roj		4,069.8		4,681.6		4,788		4,681.6		4,069.8	
Q		4,210.98		4,143.36		4,222.8		4,112.96		2,60392	
bj		**0.97**		**1.13**		**1.13**		**1.14**		**1.56**	
		Bottleneck		Underused		Underused		Underused		Underused	

Production Available Capacity (PAC) (Units/year)					PAC	PAC	KLC *Capacity loss coefficient*	*Capacity utilization*
P1	P2	P3	P4	P5	constraint	essential		
86,209	100,787	101,139	101,532	139,415	86,209	100,787	14%	103%
10,616	12,411	12,454	12,503	17,167	10,616	12,411	14%	103%
1,021	1,193	1,197	1,202	1,650	1,021	1,193	14%	103%

TABLE 9: Production Available Capacity (PAC).

As seen following the above analysis, it can be concluded that the operation (P1) "Preparing to print" presents a bottleneck, or limiting this process is the ability of the production system analysis. This situation causes a high loss of capacity up to 14% compared to homogeneous group of assets installed higher economic value and over-utilization of installed capacities of 103% generally to meet the projected production plans; which it determines that the press may not technological conditions and current working arrangements meet forecasted production plans. The possible production for the year is forecast, in line with developed analysis is (Table 10):

Nomenclature	**Potential production** (units per year)
Labels-Stickers	86,209
Triptychs	10,616
Gigantographies	1,021

TABLE 10: Potential Production 2016.

Step 12. Analysis of working conditions. To investigate the working conditions it was decided to apply a survey to 100% of printing workers. The obtained data were processed in the IBM SPSS Statistics 21.0. The applied survey underwent a test in 30% of the initial sample selected, in order to correct errors in their preparation, in order to assess the reliability and validity of the instrument to use. In all the conditions were right questions, are not relevant deficiencies noted in this regard.

Phase 4. Adjustment of organizational and technical measures to improve the elements of work organization in the selected process

In this phase a set of measures that allow senior management of printing, increased labor productivity with the current technological conditions and prevailing labor laws are developed. For the implementation of these measures will take into consideration the subordination to the restrictions in force, with adjustments to forecasted production lots.

Step 13. Identification of organizational technical measures. Is proposed as a measure regarding strategic decisions of capabilities, maintain the installed capacities, as well as the current labor regime, demonstrating to senior management of printing the need for an engineering study of

methods to assess from intensive way possible improvements in the working methods currently being developed. For strategic decision capacity utilization following is proposed:

Strategy 1. Launch the production batches from the current for this it is proposed limiting capacity (LC): 86,209 labels-stickers, 10,616 triptyches, and 1,021 gigantographies. Table 11 shows the results of this strategy are as follows:

Products	**Production** (u/year)	**Price** ($/u)	**Total** ($/year)	**Variable Cost** ($/u)	**Total** ($/year)	**Fixed Cost** ($/year)	**Profits** ($/year)
Labels-sticker	8,6209	3.00	258,627.0	1.50	129,313.5		
Triptyches	10,616	1.00	10,616.0	0.50	5,308.0		
Gigantographies	1,021	30.00	30,630.0	9.00	9,189.0		
Total			**299,873.0**	**-**	**143,810.5**	**29,000.0**	**127,062.5**

TABLE 11: Strategy 1.

This strategy generates an annual profit before taxes and interest of $ 127,062.5 per year. From the point of view of the market can only fulfill commitments ***Predicted Demand***: A 96.64% for labels-stickers, a 96.64% for triptyches and 96.68% for the gigantographies. This determines that it can not cover 100% none of the predicted demands, which will significantly influence the response levels of printing while shares plaintiffs market could be affected, given the unattractive responsiveness of the system in analysis.

Strategy 2. Launch the production batches from producing all the demand for labels-stickers, triptychs and then finally gigantographies. Table 12 presents the strategy:

Products	**Production** (u/year)	**Price** ($/u)	**Total** ($/year)	**Variable Cost** ($/u)	**Total** ($/year)	**Fixed Cost** ($/year)	**Profits** ($/year)
Labels-stickers	89,200	3.00	267,600.00	1.50	133,800.0		
Triptychs	8,804	1.00	8,804.00	0.50	4,401.8		
Totales			**276,404.0**	**-**	**138,201.8**	**29,000.0**	**109,201.8**

TABLE 12: Strategy 2.

The above strategy will fulfill the commitments for the production of labels-stickers with a production volume of 89,200 units per year. Similarly it will be compliant with a volume of up to 8,804 triptychs units per year. All this will contribute a profit of $ 109,201.8 a year. This strategy will only fill 100% of commitments for labels-stickers, 80% for triptychs and 0% for gigantographies, which will affect the possible loss of market share for these products, while according to economic indicators it is less productive than strategy 1.

Strategy 3. Launch the production batches from all the demand for produce triptychs, gigantographies and then finally labels-stickers. Table 13 presents the strategy:

Products	**Production** (u/year)	**Price** ($/u)	**Total** ($/year)	**Variable Cost** ($/u)	**Total** ($/year)	**Fixed Cost** ($/year)	**Profits** ($/year)
Triptychs	10,984	1.00	10,984.0	0.50	5,492.0		
Gigantographies	1,056	30.00	31,680.0	9.00	9,504.0		
Labels-stickers	85,670	3.00	257,011.0	1.50	128,505.6		
Total			**299,675.0**	**-**	**143,501.6**	**29,000.0**	**127,173.6**

TABLA 13: Strategy 3.

The above strategy will fulfill the commitments for production: triptychs with 100% of the forecasted demand (10,984 units per year), just as it will cover the predicted demand of gigantographies of 1056 units per year, while only you can meet the demand of labels-stickers in a 96.04%, which will affect the possible loss of market share for this product, since it is not achieved in 100% satisfy demand. Line with the economic indicators evaluated this strategy will allow an upward gain to $ 127,173.6 per year, recognizing from the production order as the most attractive of the previously evaluated strategies (strategies 1 and 2, respectively).

Strategy 4. Launch the production batches from producing all the demand for gigantographies, then labels-stickers and finally triptychs. Table 14 presents the results.

As you can see the fourth strategy will facilitate compliance with production commitments: 100% of the forecasted demand (1056 units per year) of gigantographies, likewise will cover the predicted demand for stickers from 89200 units a year, while it is able to meet the demand of triptychs in a 77.44%, which will affect the possible loss of market share for this product, since it is not achieved in 100% satisfy demand. Line with the economic indicators evaluated this strategy will allow an upward gain to $131,229.50 per year, observed this strategy from the point of view of production as the most competitive strategies before analyzed.

Products	**Production** (u/year)	**Price** ($/u)	**Total** ($/year)	**Variable Cost** ($/u)	**Total** ($/year)	**Fixed Costo** ($/year)	**Profits** ($/year)
Gigantographies	1,056	30.00	31,680.0	9.00	9,504.0		
Labels-stickers	89,200	3.00	267,600.0	1.50	133,800.0		
Triptychs	8,507	1.00	8,507.0	0.50	4,253.5		
Total			**307,787.0**	**-**	**147,557.5**	**29,000.0**	**131,229.5**

TABLE 14: Strategy 4.

Generally one can assert that in the evaluated strategies, given the subordination of the production system to technological and labor regime restrictions, always cause low satisfaction of the demands projected for each of the products under analysis. Just as each of the strategies given combination is able to optimize the indicator of earnings, as production scheduling is decided.

All this determines that: It is the opinion of this researcher that among the alternatives evaluated, the most desirable from the production order is the strategy 3, which even generates a 3.09% (4,055.9 dollars per year) dollars lower earnings strategy 4 enables better alternatives profit strategies 1 and 2, respectively, in turn allows, on strategies 1, 2 and 4, to reach a larger market share, leaving satisfied only 3.96% of the demand labels and stickers, and achieving a balance between production important indicators, earnings and market shares.

Step 14. Implementation of the technical and organizational measure. This step is suggested to address the press to take the **third strategy** for its implementation.

4. CONCLUSIONS

The theory of constraints is a discipline relevant to the analysis of labor productivity, which has been recognized by several authors, who insist raise the need to assume comprehensively and from a holistic perspective for analysis.

The theoretical review developed research indicates the existence of a wide variety of approaches to the theory of constraints, which a group of authors manifest from the quantitative edge, in other linking this with the qualitative and less as highlights those addressing it from the holistic nature.

From the deficiencies found in the literature a procedure for the management of physical restraint was divided into four phases which are based on the selection and preparation of the team, characterization of the organization with its human capital and processes developed, to continue the analysis of each of the elements of the organization and present an analysis so that it can be a set of organizational technical measures to improve productivity.

About 15% of time was observed interruptions in operations 2 and 5, respectively, which decreases the overall production capacity. Similarly productive to increase the rate of performance of these operations were identified reserves.

You can argue that with assessed strategies, always low satisfaction of the demands designed to each of the products cause analysis. Similarly, each of the strategies, given their combination, is able to optimize the indicator of earnings, as production scheduling is decided. This determines suggest that the most desirable from the production order is the strategy 3, which even generates a 3.09% (4,056.00 dollars per year) lower profit dollars that the strategy 4, enables better alternatives profit strategies 1 and 2, respectively, in turn allows, on strategies 1, 2 and 4, to reach a larger market share, leaving satisfied only 3.96% of the demand for labels and stickers, and achieving an important balance between production indicators, earnings and market shares.

It is recommended for new directions in studies of this subject, to continue with the application in other scenarios of the proposed procedure, deepening in its holistic and strategic character, that contributes from the praxis to the realization of analysis from the workstations to the processes and as a consequence an improvement in productivity at work

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